LDEF
MATERIALS/CONTAMINATION

NAS 8-40581

GARY PIPPIN
BOEING DEFENSE & SPACE GROUP
JULY 1997

TOPICS

Long Duration Exposure Facility(LDEF)

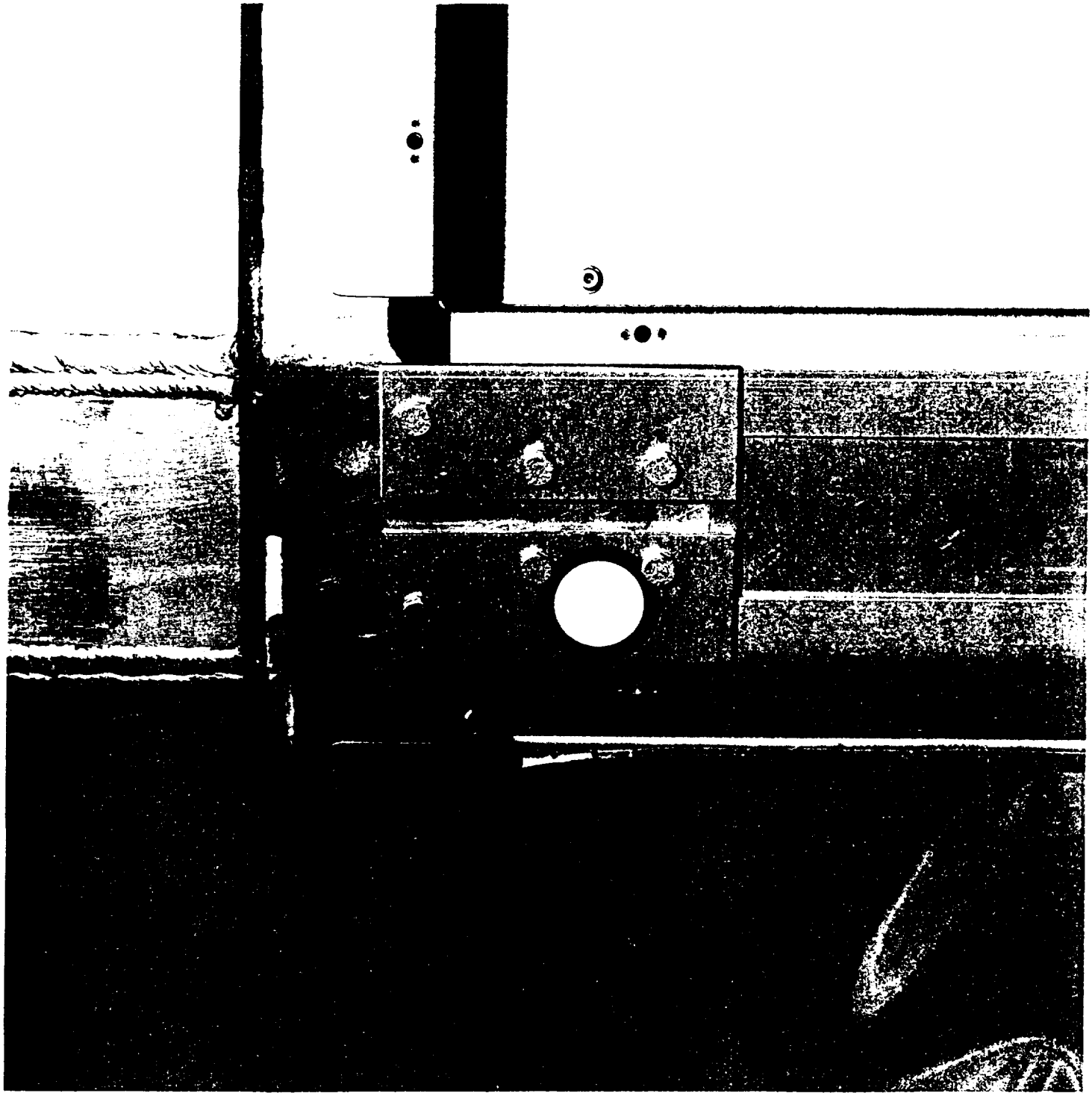
TRAY CLAMP BOLT HEADS

UHCRE FLIGHT EXPERIMENT TRAY WALLS

Effects of the Space Environment on Materials(ESEM) FLIGHT EXPERIMENT

Passive Optical Sample Assembly(POSA) I and II FLIGHT EXPERIMENTS

This chart is to introduce the topics covered in this presentation. I will review the post-flight analysis results from two types of hardware from the Long Duration Exposure Facility. I will also show flight hardware for one upcoming and two current flight experiments evaluating the performance of materials in space. These flight experiments also are concerned with contamination effects which will also be discussed.

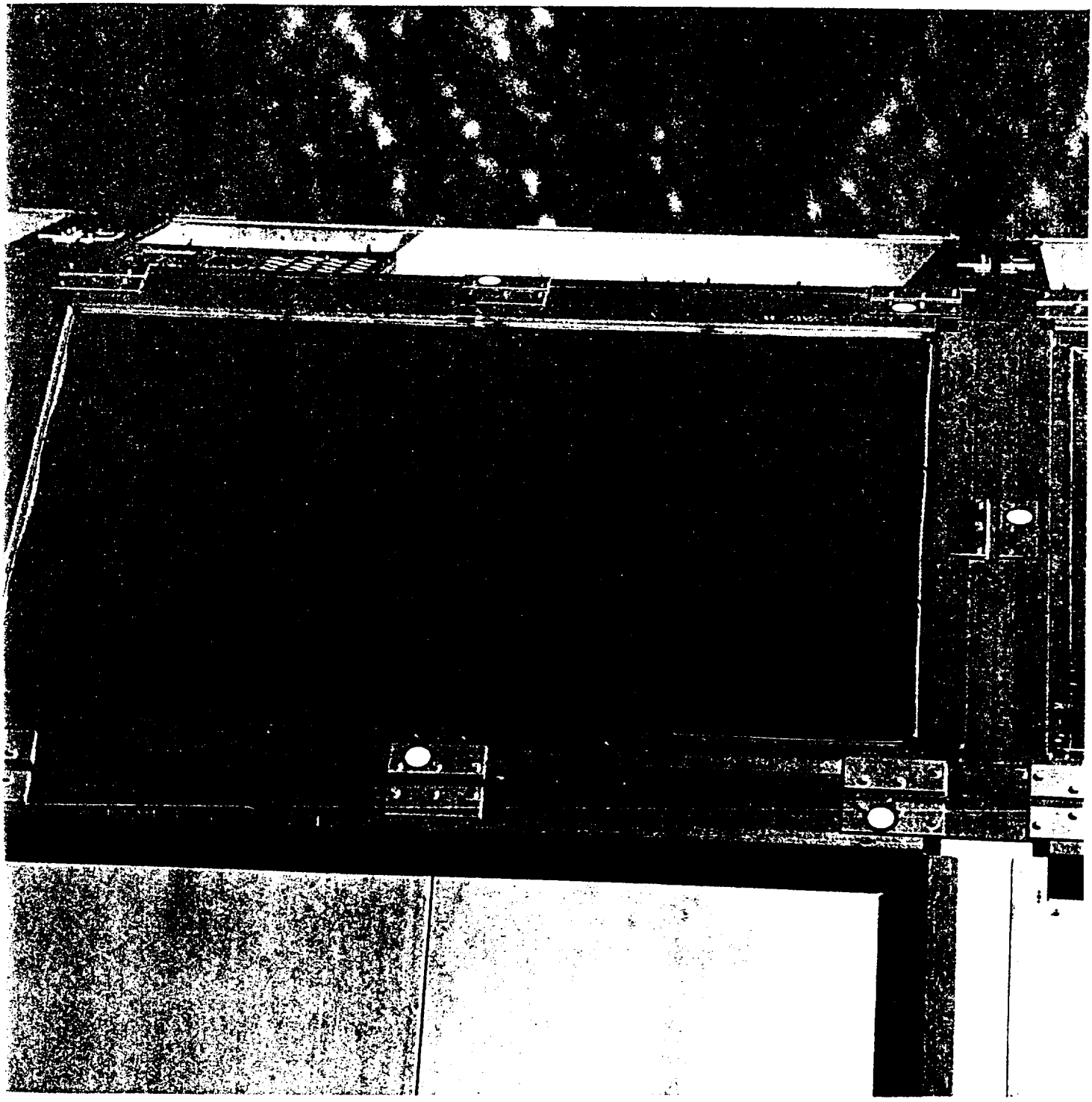


Tray clamp & bolts-this NASA photo shows the tops of some LDEF tray clamp bolts. These surfaces were analyzed post-flight for silicon containing contaminants.

NASA National Aeronautics and Space Administration

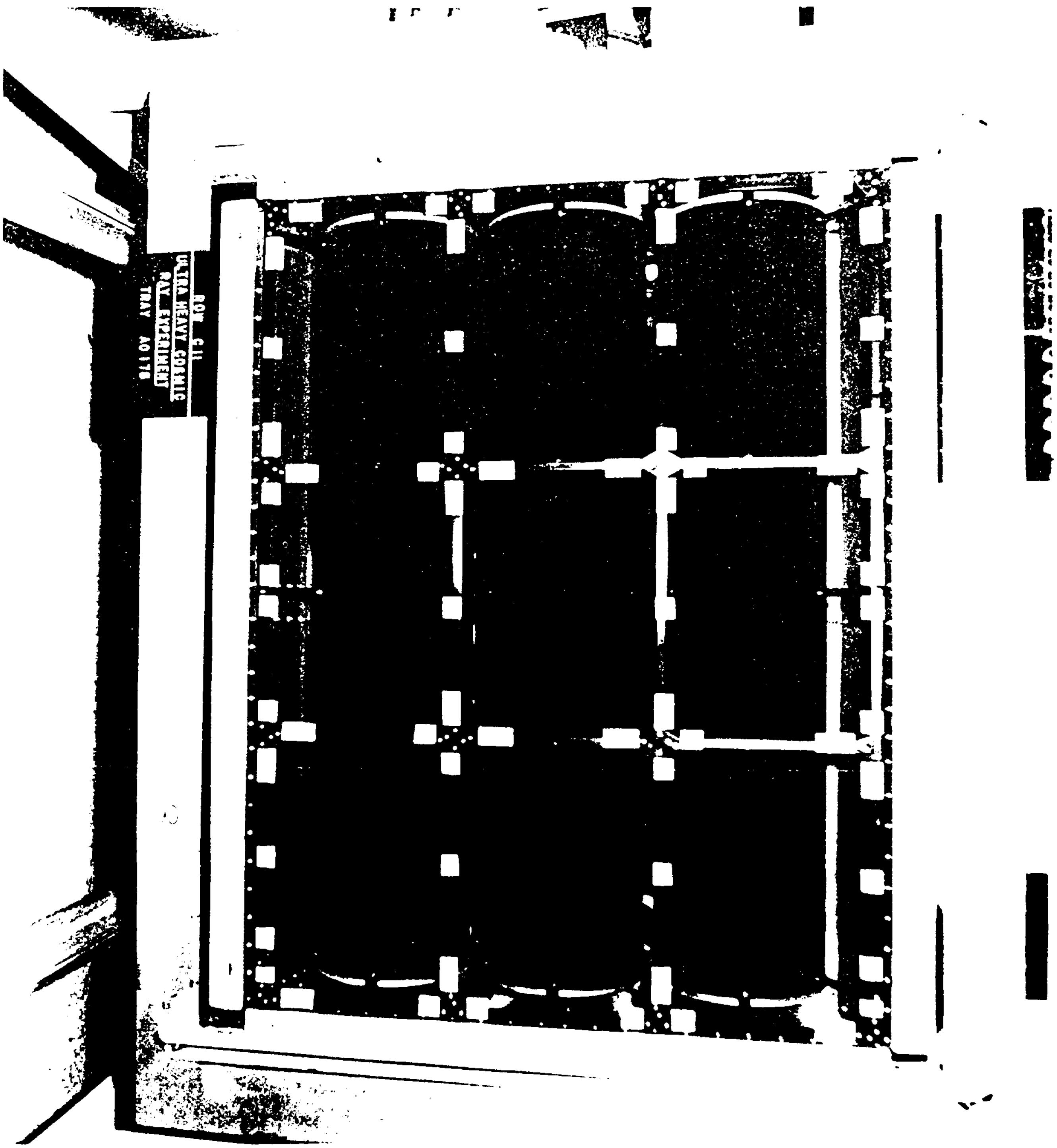
S32-76-101

Lyndon B. Johnson Space Center
Houston, Texas 77058



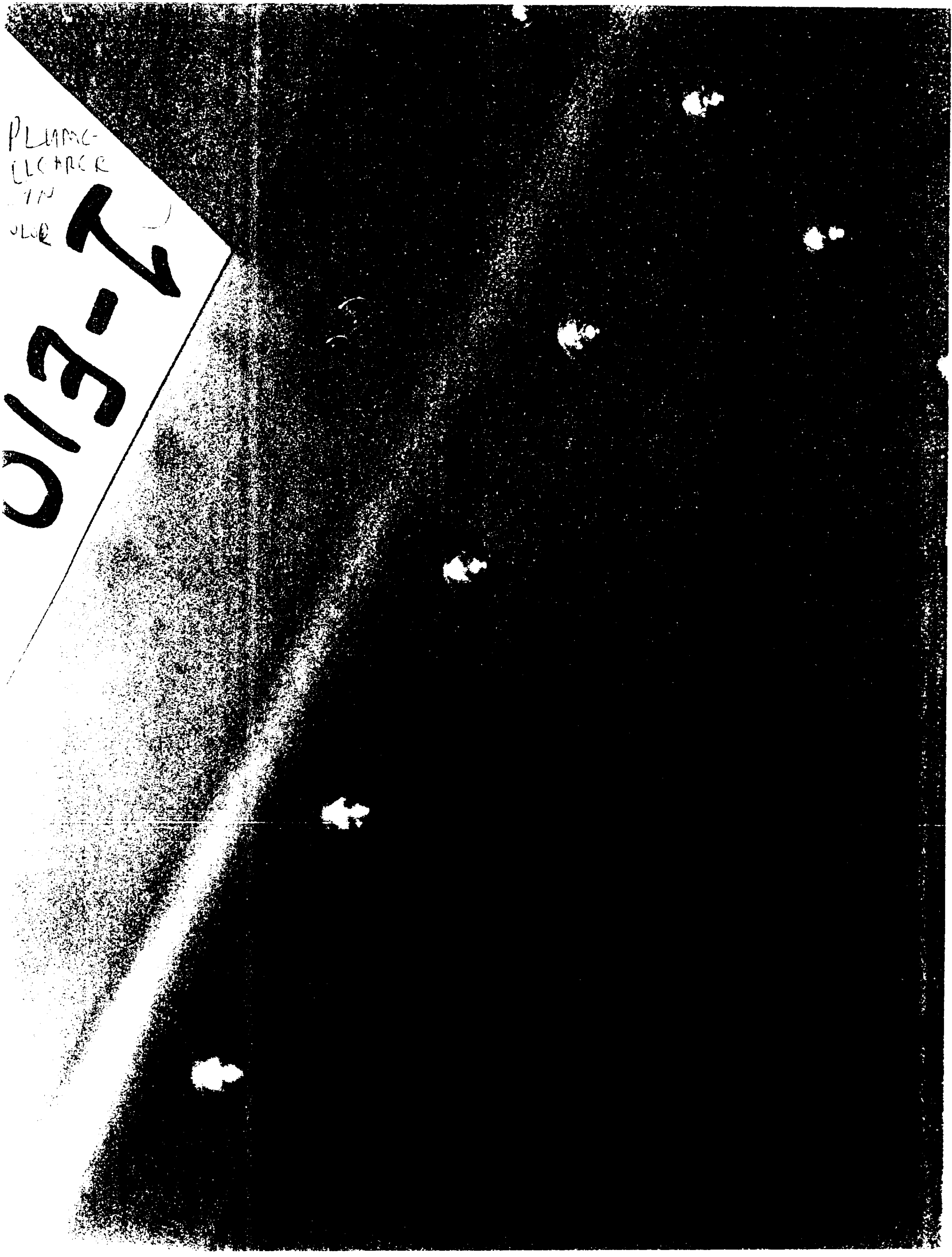
On-orbit view of vent holes in blanket. This NASA photo of the LDEF on-orbit shows the vents at the edge of thermal control blankets on the European Heavy-Cosmic-Ray experiment. Adhesive under the blanket outgassed through these vents and deposited on the tray surfaces. Our current NASA contract is to determine the distribution of this contaminant on selected tray surfaces.

[illegible] LOCATIONS



91-09352

Position of velcro/adhesive locations-This NASA photo shows the locations of the silicone which was the source of the contamination being analyzed on our current contract. This is to show the audience the extent of the material and the geometry of the tray interior.


013-I

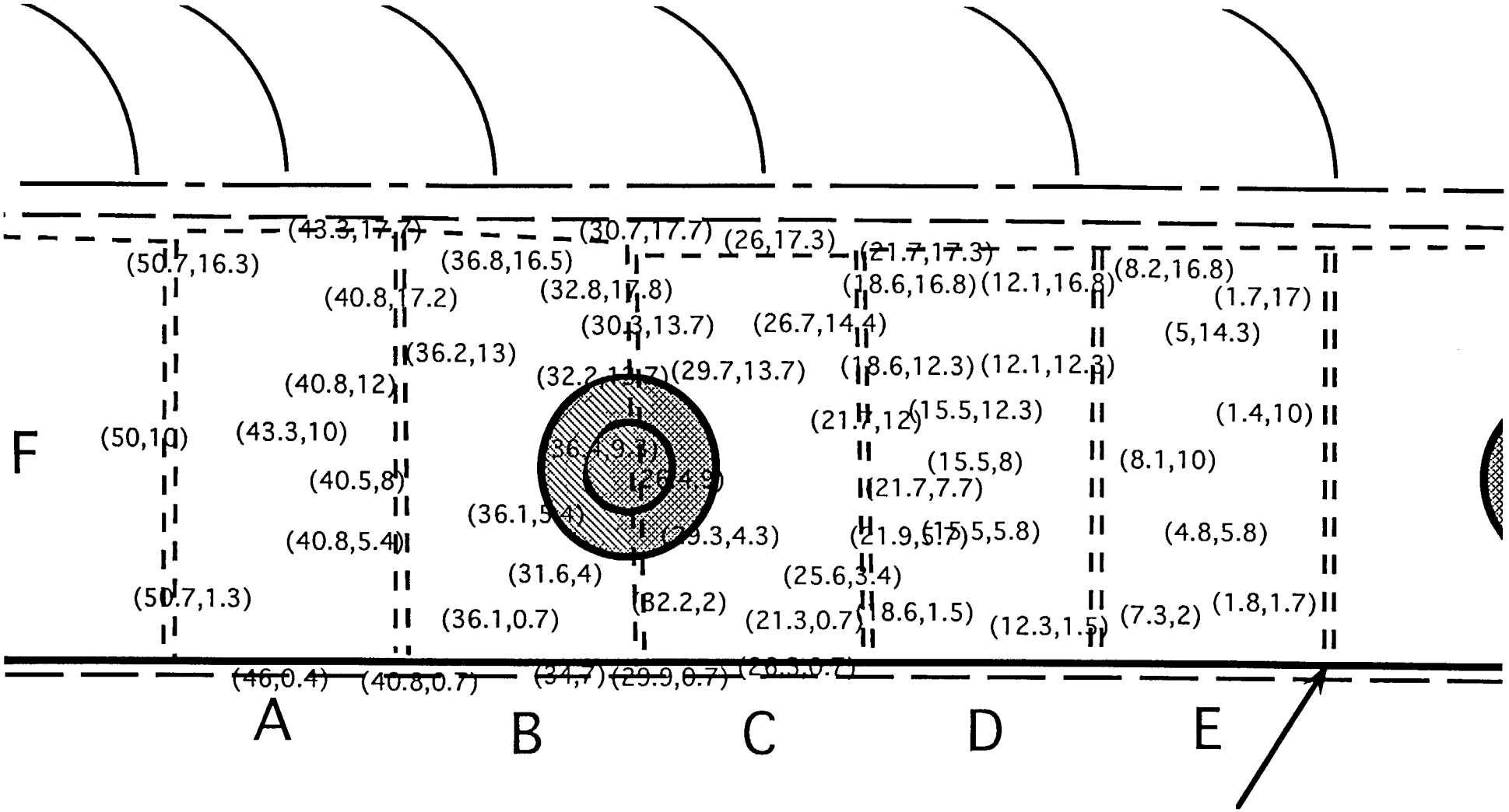
Plume-This photo taken at Boeing shows a close-up of the contamination deposit from a "leading-edge" location from LDEF. The plume which extends down the tray wall shows that a portion of the tray wall saw direct sunlight and atomic oxygen. This combined exposure produced the discoloration by fixing the silicone material to the tray surface.

RESULTS OF SURFACE Si% MEASUREMENTS and MEASUREMENT LOCATIONS

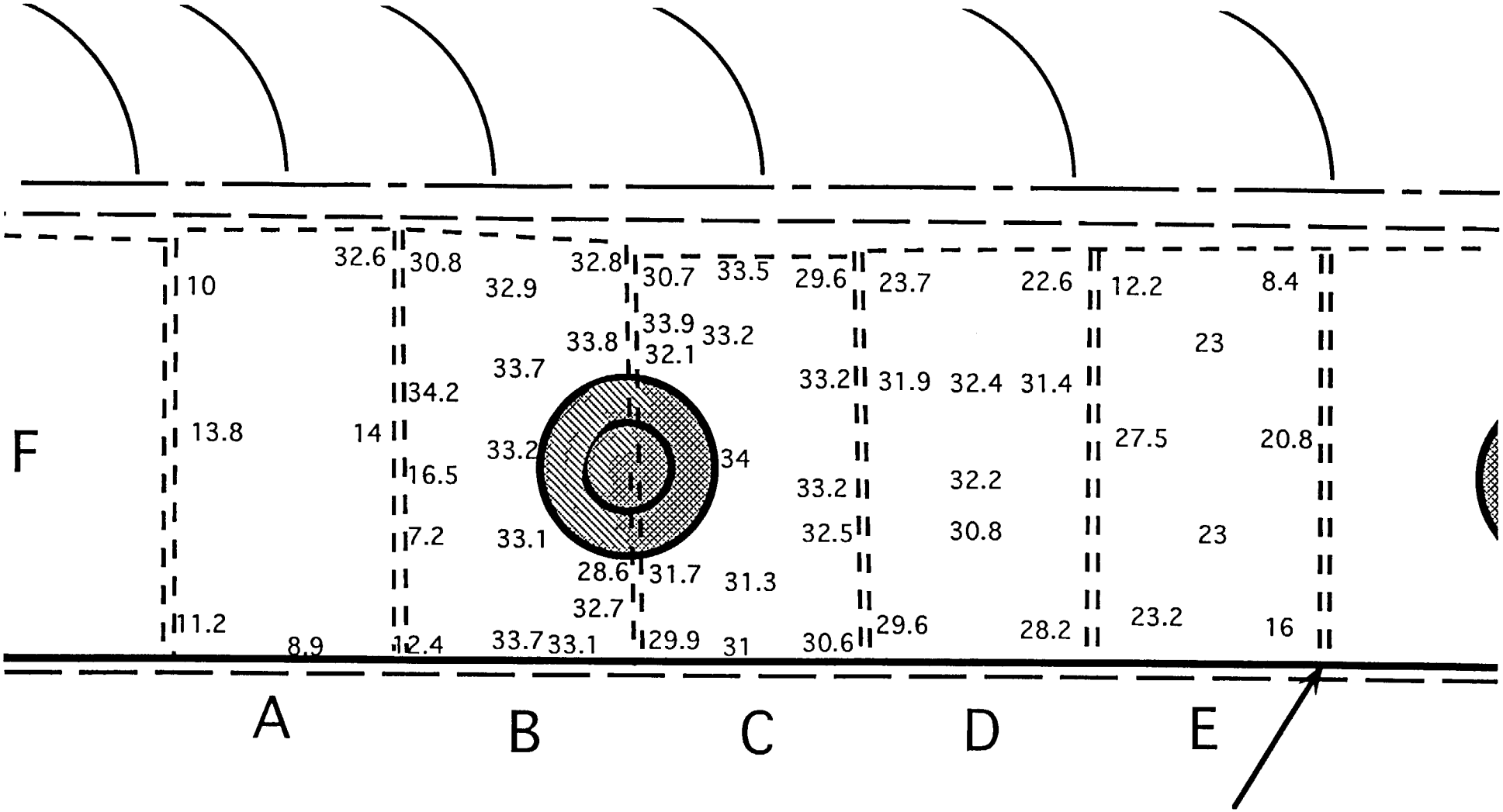
TRAYS: E10
C6
A4

This chart identifies the locations for which a detailed analysis of the amount of silicon present on the surface was determined. E10 is an area with high solar and atomic oxygen exposure, C6 is an area of high solar exposure and moderate amounts of atomic oxygen exposure, and A4 is an area with high solar exposure and no atomic oxygen exposure.

The next several charts detail the results of the measurements made on the selected surfaces from the Long Duration Exposure Facility. These charts show the location of individual measurements and the results (the % silicon detected at each site). Some of the data will be shown and the rest I will have as backup charts in case someone wants to see data from a specific location. One of these charts shows a depth profile of the deposited contaminant, showing the thickness of the deposit.


(43.3,17.7)
(30.7,17.7)
(26,17.3)
(21.7,17.3)
(50.7,16.3)
(36.8,16.5)
(18.6,16.8)
(12.1,16.8)
(8.2,16.8)
(40.8,17.2)
(32.8,17.8)
(1.7,17)
(30.3,13.7)
(26.7,14.4)
(5,14.3)
(36.2,13)
(29.7,13.7)
(18.6,12.3)
(12.1,12.3)
(40.8,12)
(15.5,12.3)
(1.4,10)
F
(50,10)
(43.3,10)
(21.7,12)
(15.5,8)
(8.1,10)
(40.5,8)
(21.7,7.7)
(36.1,5.4)
(21.9,5.7)
(15.5,5.8)
(4.8,5.8)
(40.8,5.4)
(31.6,4)
(25.6,3.4)
(50.7,1.3)
(B2.2,2)
(36.1,0.7)
(21.3,0.7)
(18.6,1.5)
(12.3,1.5)
(7.3,2)
(1.8,1.7)
(46,0.4)
(40.8,0.7)
(34,?)
(29.9,0.7)
A
B
C
D
E
Origin for grid names (0,0) is at
lower, right corner of piece E

E10-8

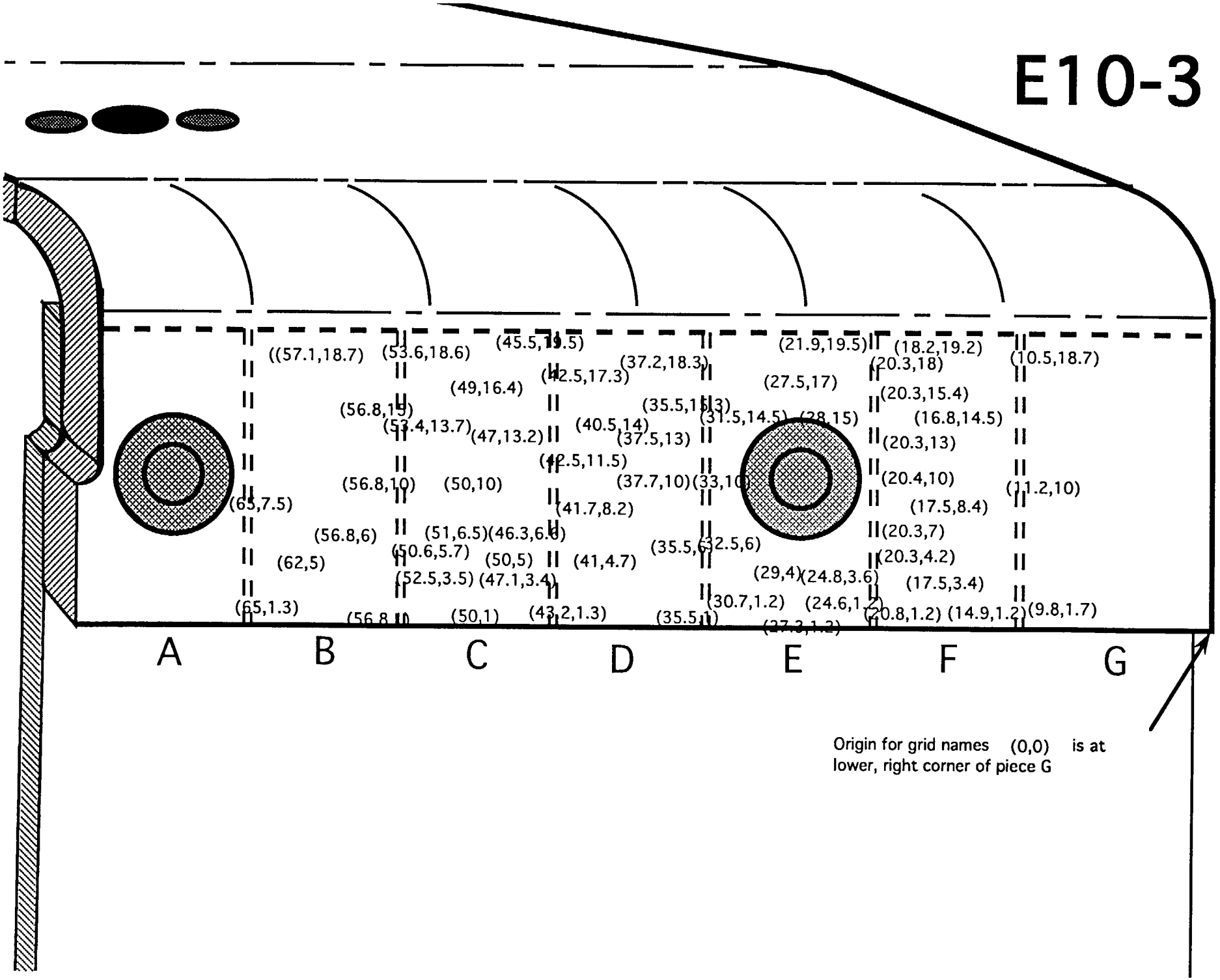


Percent Silicon

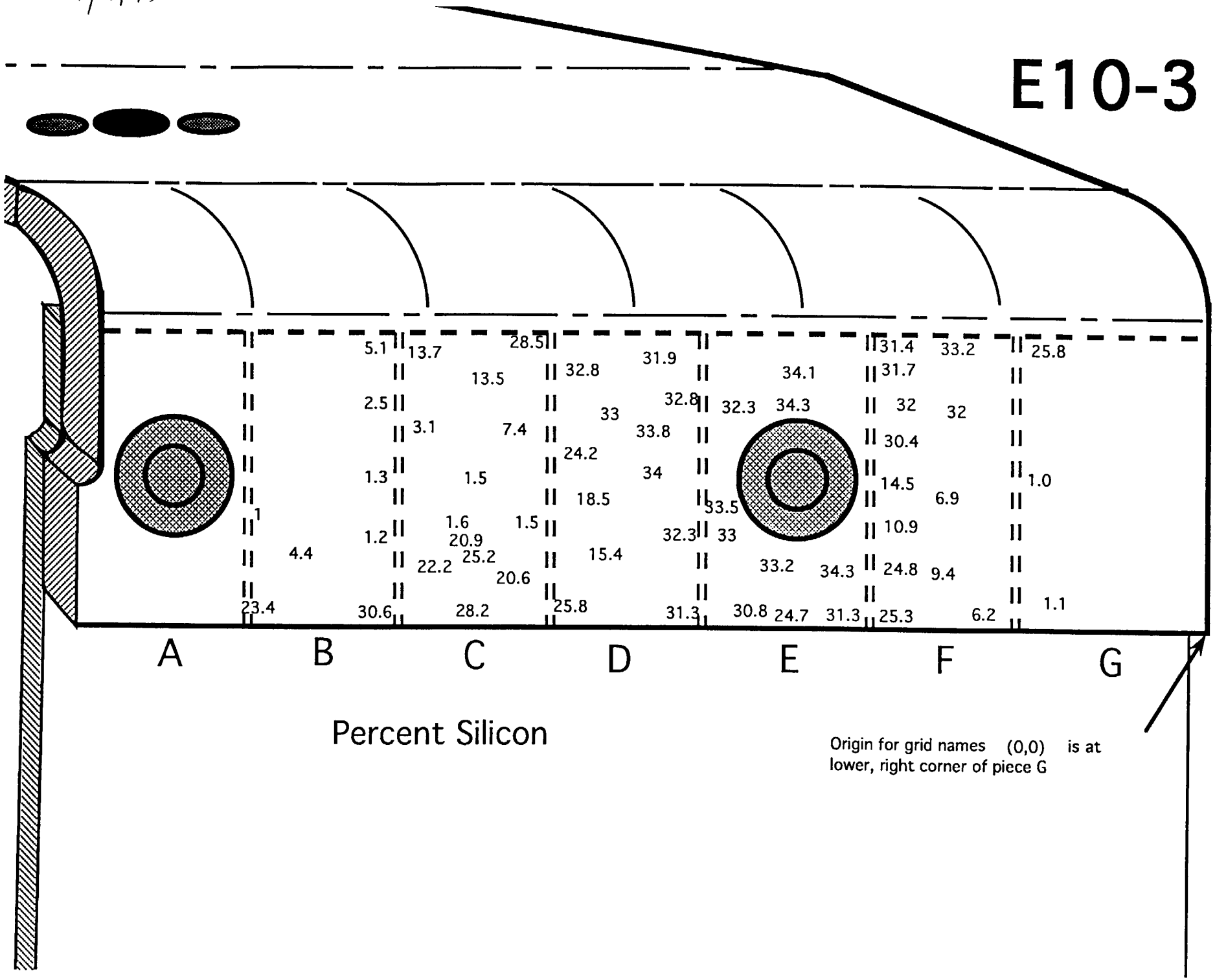
Origin for grid names (0,0) is at lower, right corner of piece E

E10-8

E10-3


((57.1,18.7)
(53.6,18.6)
(45.5,19.5)
(37.2,18.3)
(21.9,19.5)
(18.2,19.2)
(10.5,18.7)
(49,16.4)
(42.5,17.3)
(27.5,17)
(20.3,18)
(20.3,15.4)
(56.8,15)
(53.4,13.7)
(47,13.2)
(40.5,14)
(37.5,13)
(35.5,15.3)
(31.5,14.5)
(28,15)
(16.8,14.5)
(20.3,13)
(42.5,11.5)
(56.8,10)
(50,10)
(37.7,10)
(33,10)
(20.4,10)
(11.2,10)
(65,7.5)
(41.7,8.2)
(17.5,8.4)
(56.8,6)
(51,6.5)
(46.3,6.6)
(35.5,6)
(32.5,6)
(20.3,7)
(50.6,5.7)
(62,5)
(50,5)
(41,4.7)
(20.3,4.2)
(29,4)
(24.8,3.6)
(52.5,3.5)
(47.1,3.4)
(17.5,3.4)
(65,1.3)
(30.7,1.2)
(24.6,1.2)
(56.8,1.0)
(50,1)
(43.2,1.3)
(35.5,1)
(27.3,1.2)
(20.8,1.2)
(14.9,1.2)
(9.8,1.7)
A
B
C
D
E
F
G
Origin for grid names (0,0) is at
lower, right corner of piece G

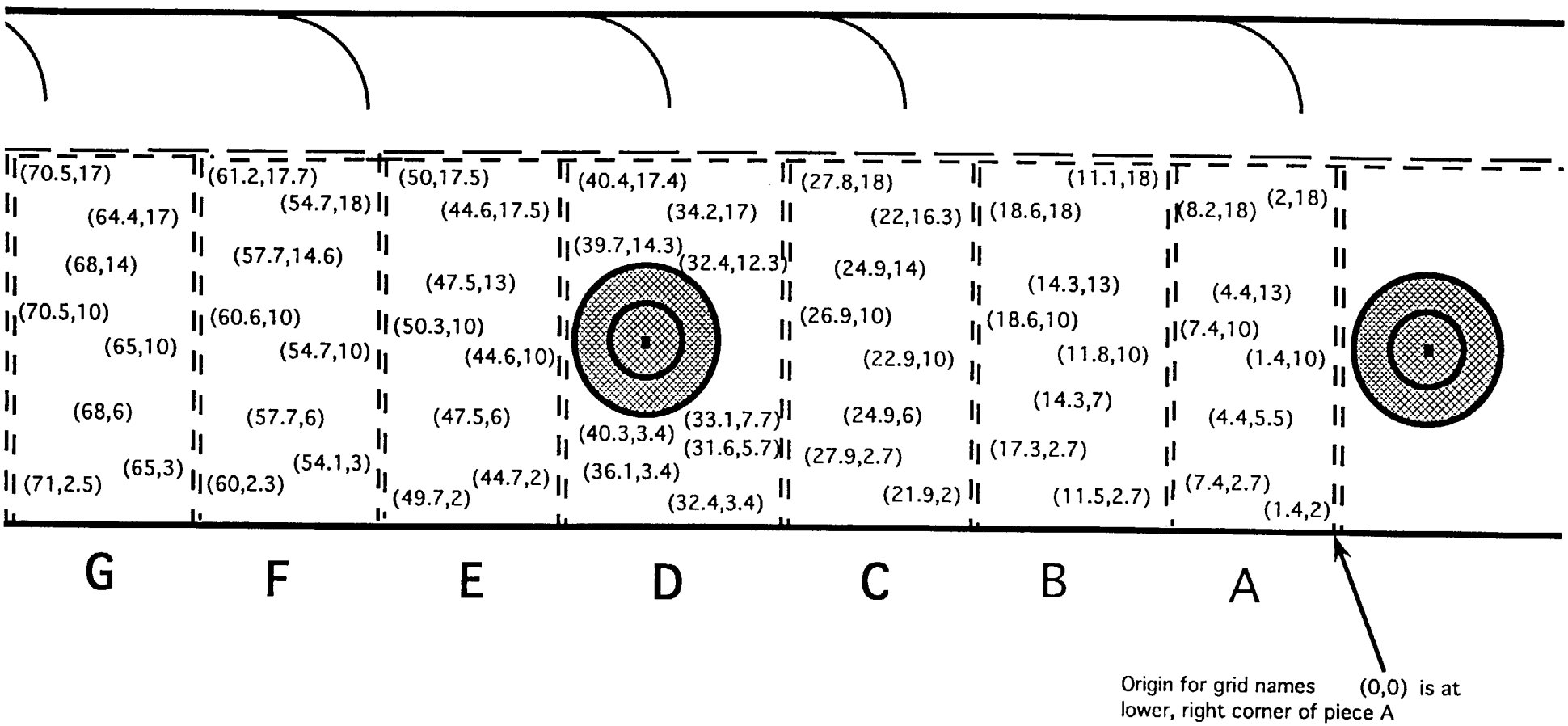
E10-3



Percent Silicon

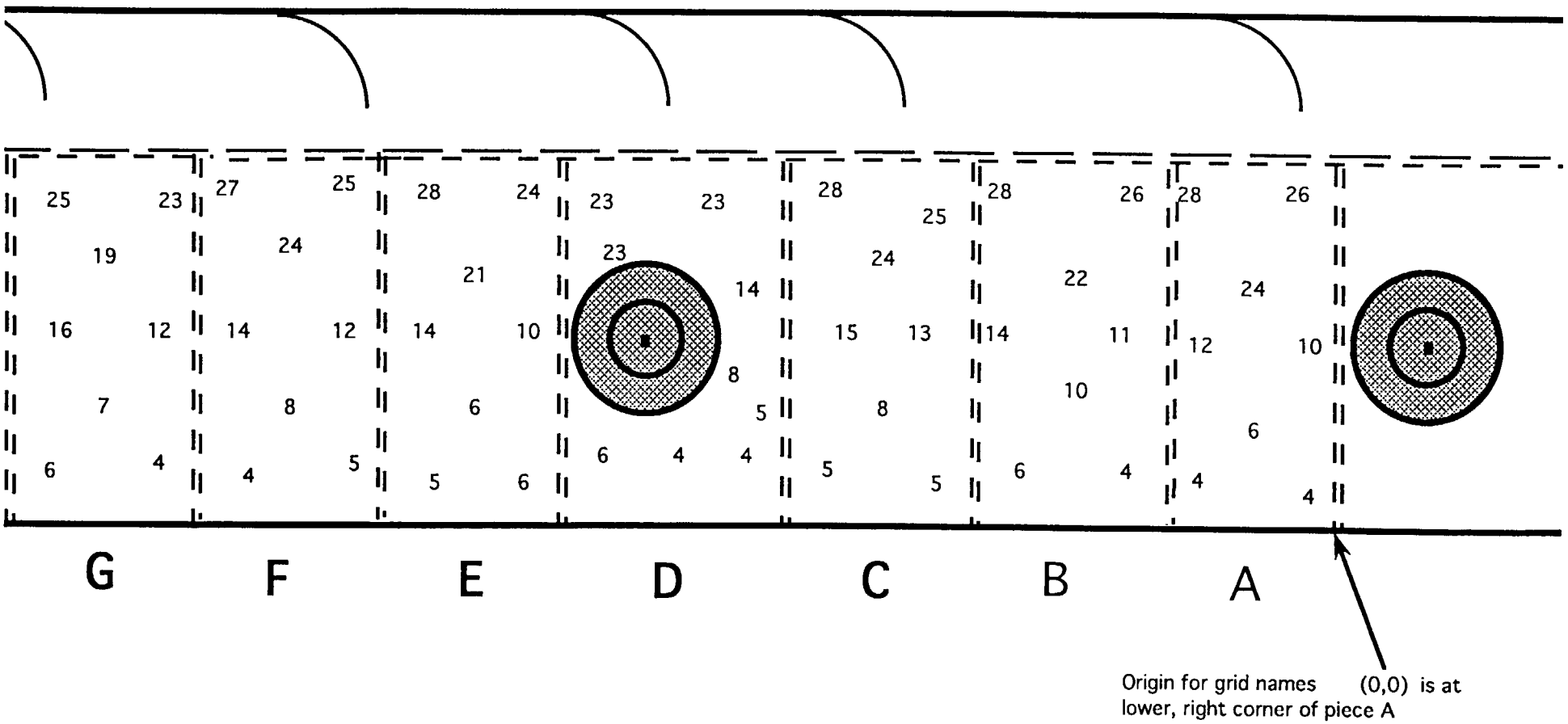
Origin for grid names (0,0) is at lower, right corner of piece G

C6

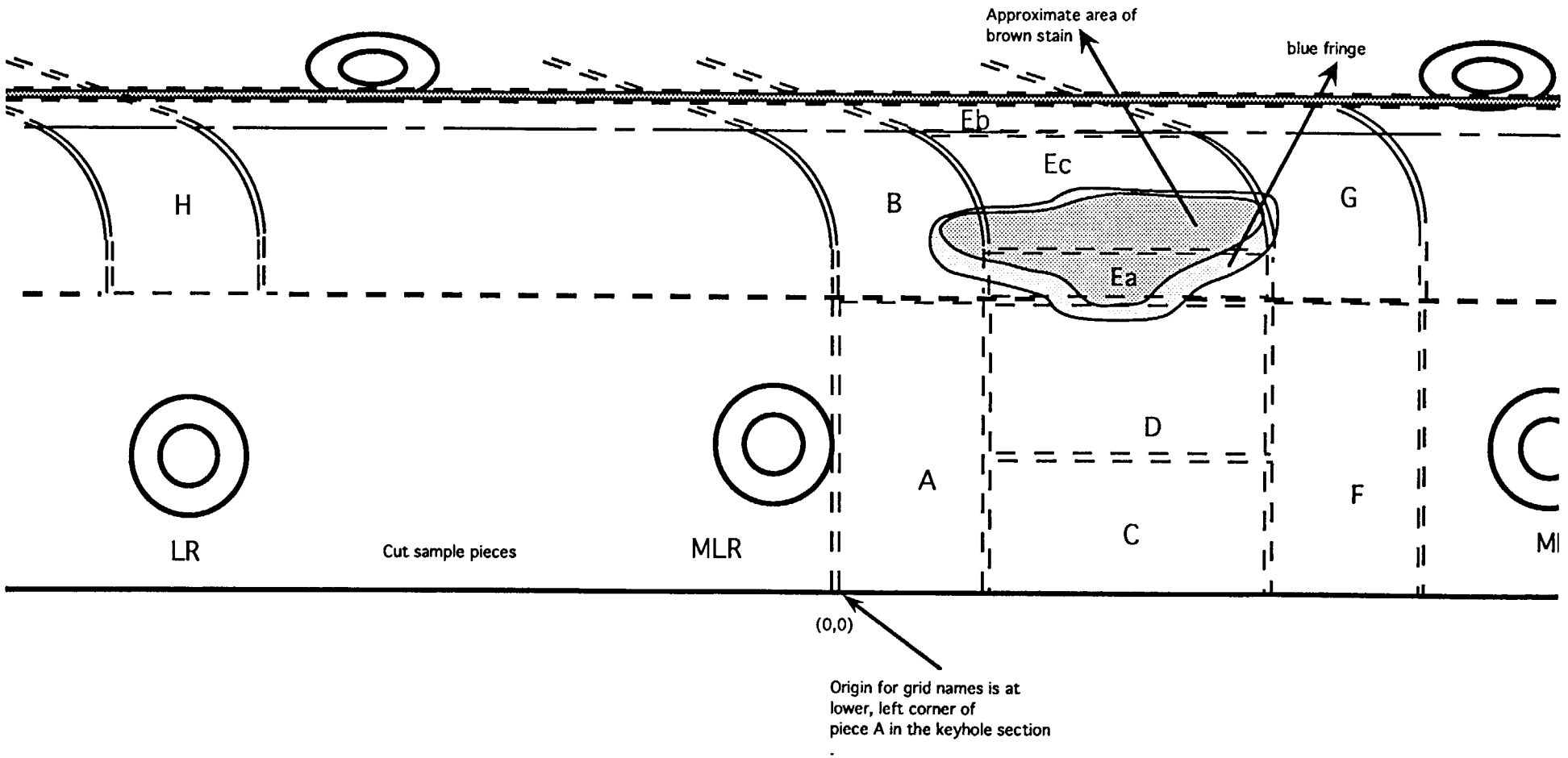

(70.5,17)
(64.4,17)
(68,14)
(70.5,10)
(65,10)
(68,6)
(65,3)
(71,2.5)
(61.2,17.7)
(54.7,18)
(57.7,14.6)
(60.6,10)
(54.7,10)
(57.7,6)
(54.1,3)
(60,2.3)
(50,17.5)
(44.6,17.5)
(47.5,13)
(50.3,10)
(44.6,10)
(47.5,6)
(44.7,2)
(49.7,2)
(40.4,17.4)
(34.2,17)
(39.7,14.3)
(32.4,12.3)
(40.3,3.4)
(33.1,7.7)
(31.6,5.7)
(36.1,3.4)
(32.4,3.4)
(27.8,18)
(22,16.3)
(24.9,14)
(26.9,10)
(22.9,10)
(24.9,6)
(27.9,2.7)
(21.9,2)
(11.1,18)
(18.6,18)
(14.3,13)
(18.6,10)
(11.8,10)
(14.3,7)
(17.3,2.7)
(11.5,2.7)
(8.2,18)
(2,18)
(4.4,13)
(7.4,10)
(1.4,10)
(4.4,5.5)
(7.4,2.7)
(1.4,2)
G
F
E
D
C
B
A
Origin for grid names
lower, right corner of piece A
(0,0) is at

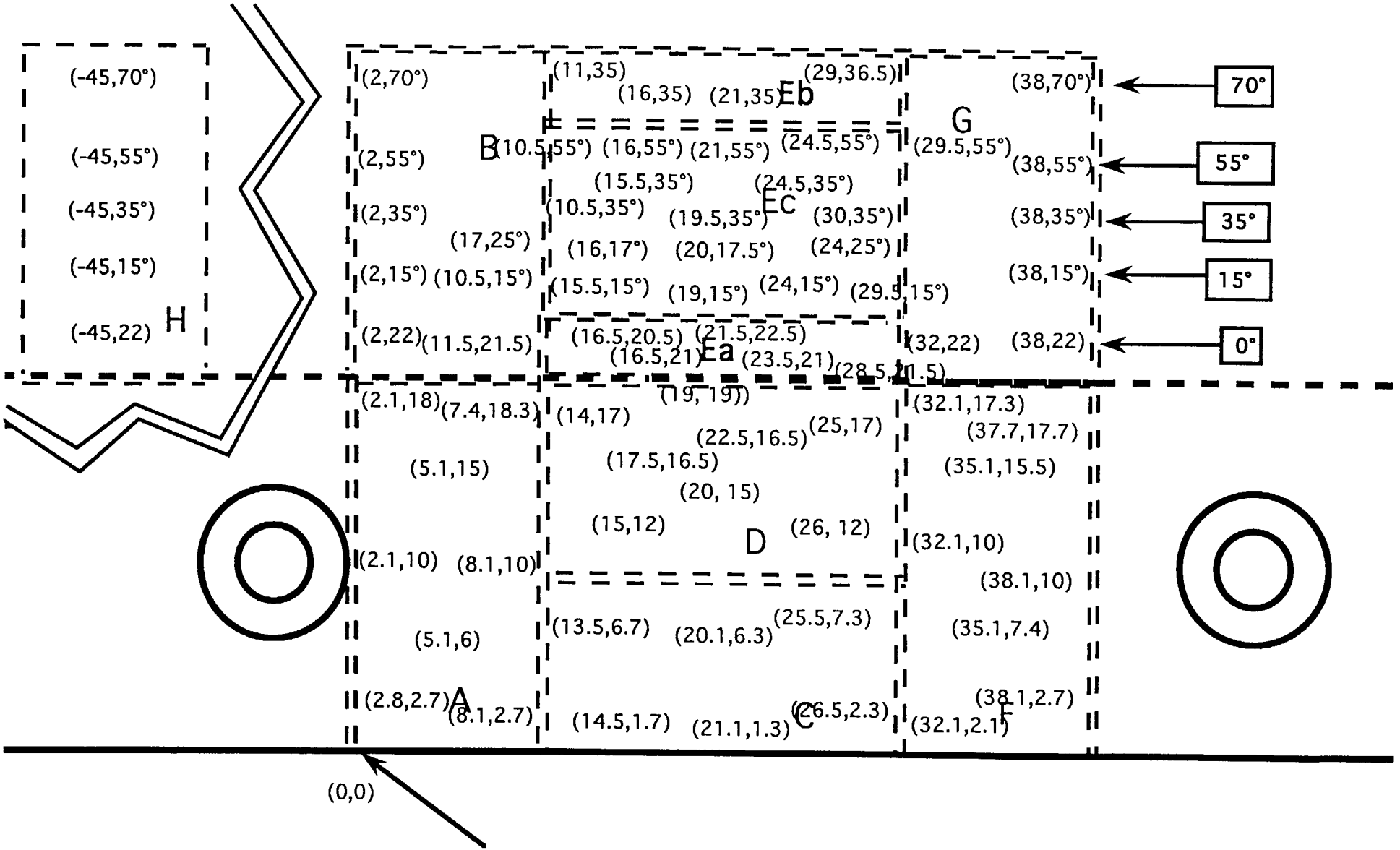
% Silicon

C6


25
23
27
25
28
24
23
23
28
28
26
28
26
19
24
23
21
14
24
25
22
24
16
12
14
12
14
10
15
13
14
11
12
10
7
8
6
8
10
6
6
4
4
5
4
5
6
4
4
5
5
6
4
4
4
G
F
E
D
C
B
A
Origin for grid names (0,0) is at
lower, right corner of piece A

C6-2


Approximate area of brown stain
blue fringe
Eb
Ec
Ea
H
B
G
D
A
F
C
LR
Cut sample pieces
MLR
MI
(0,0)
Origin for grid names is at lower, left corner of piece A in the keyhole section

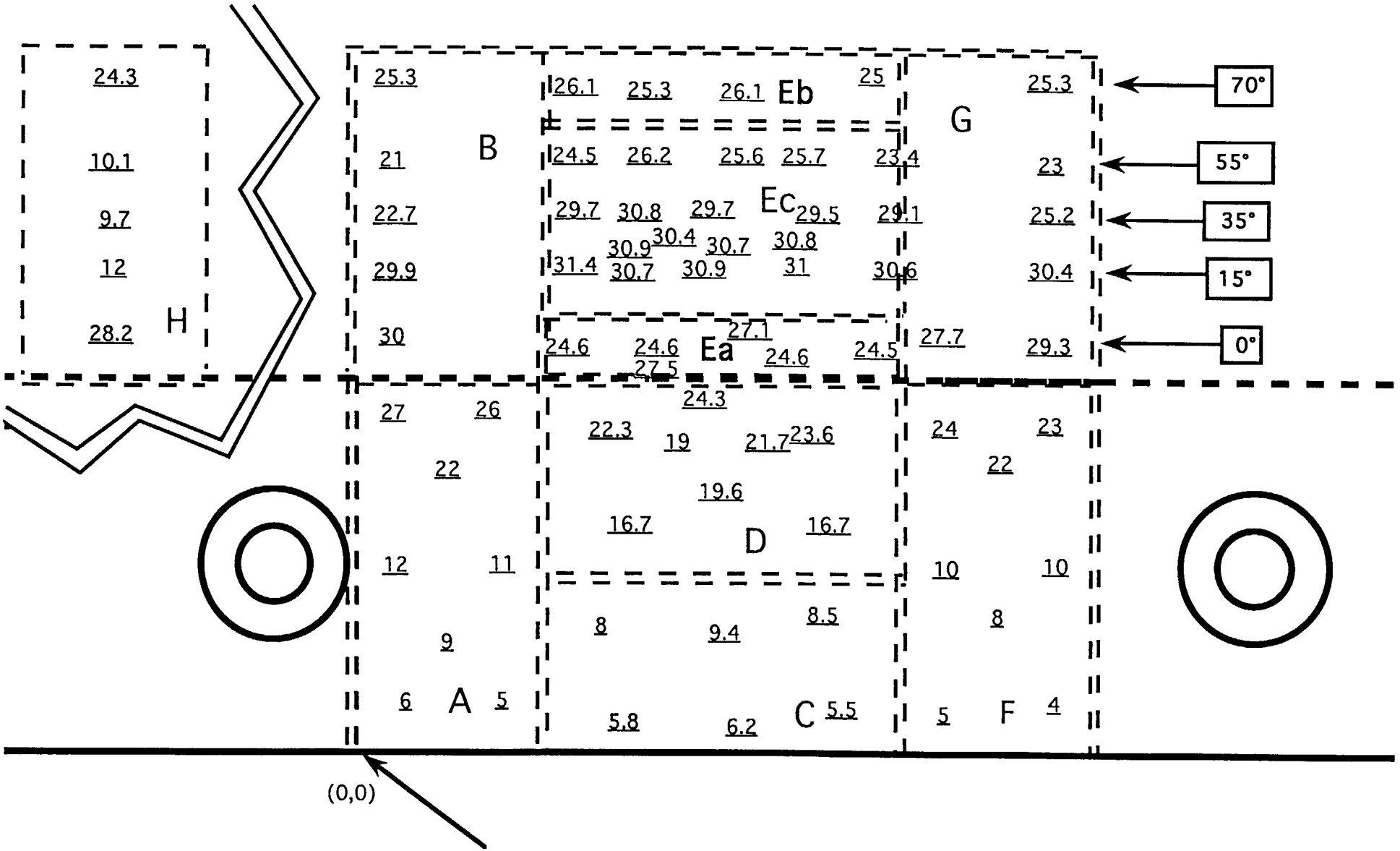


Origin for grid names is at lower, left corner of piece A in the keyhole section

C6-2

Grid names of analysis positions

'Unbent' sample pieces

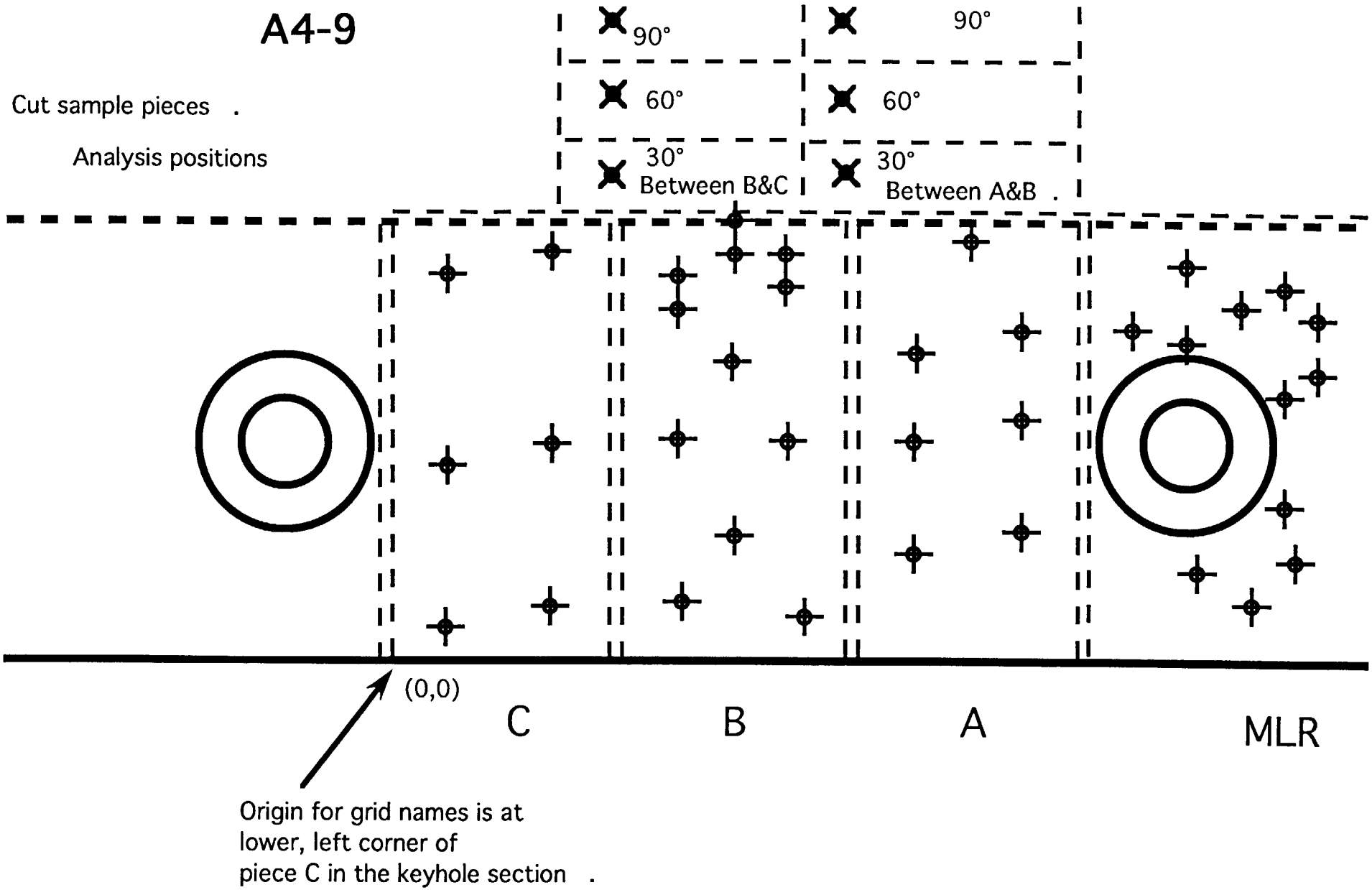


'Unbent' sample pieces

A4-9

Cut sample pieces .

Analysis positions

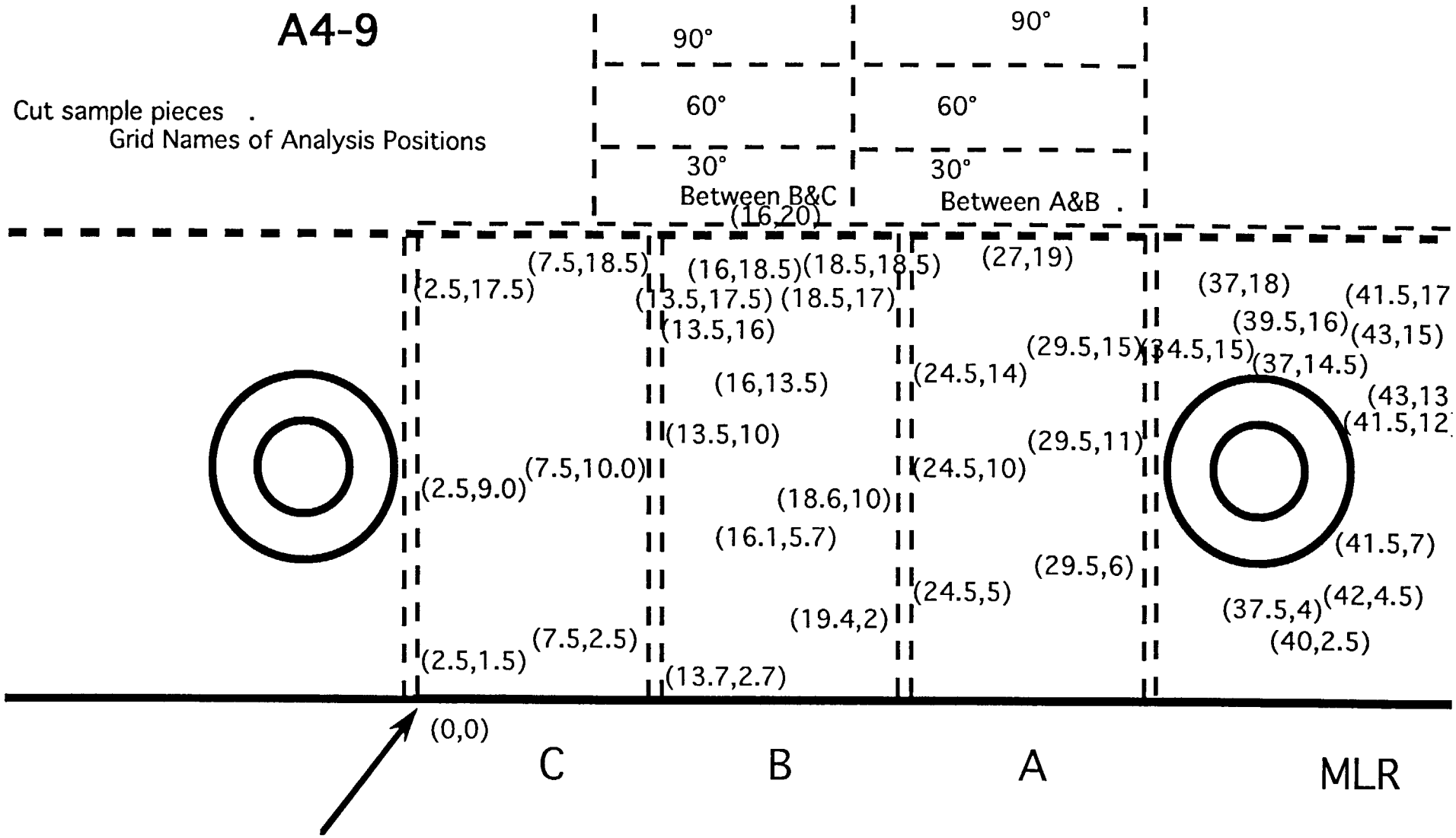


Origin for grid names is at lower, left corner of piece C in the keyhole section .

Each analysis area is a 0.6mm diameter circle centered on the point described by the grid name .

A4-9

Cut sample pieces .
Grid Names of Analysis Positions



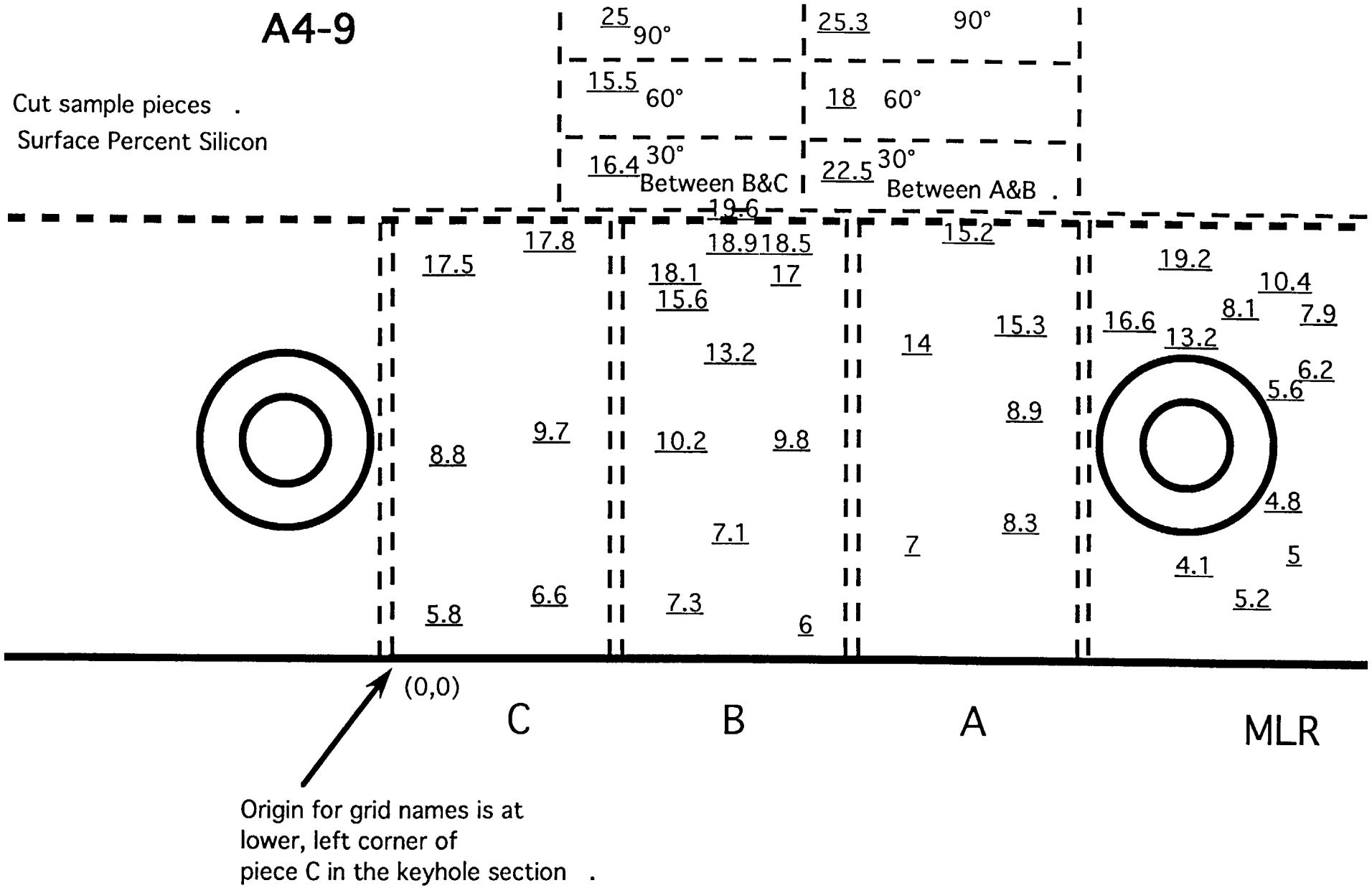
Origin for grid names is at lower, left corner of piece C in the keyhole section . which is 1.0mm to the right of the right edge of the left rivet.

Coordinates are given in (-x-mm, -y-mm) .

A4-9

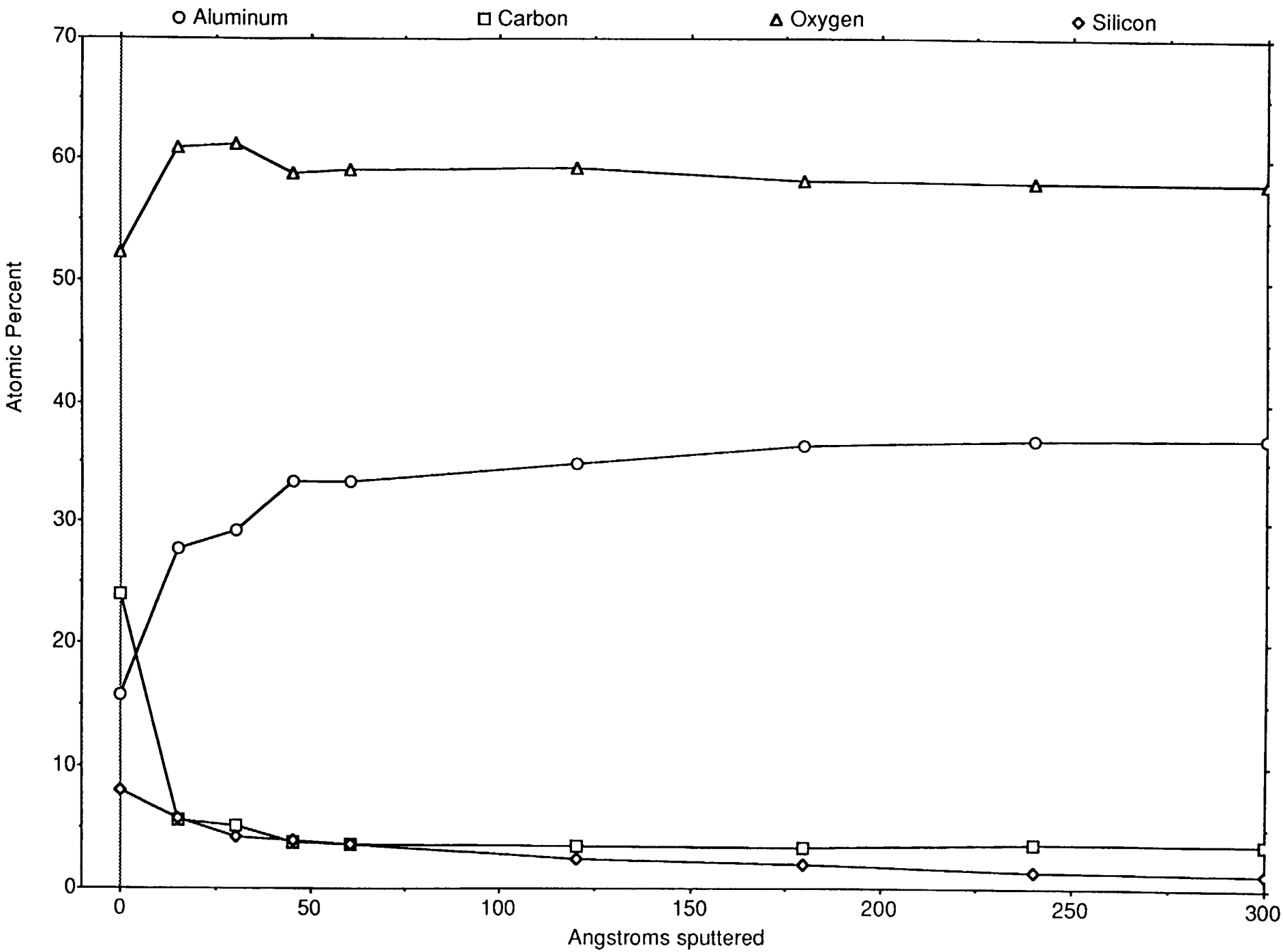
Cut sample pieces .

Surface Percent Silicon



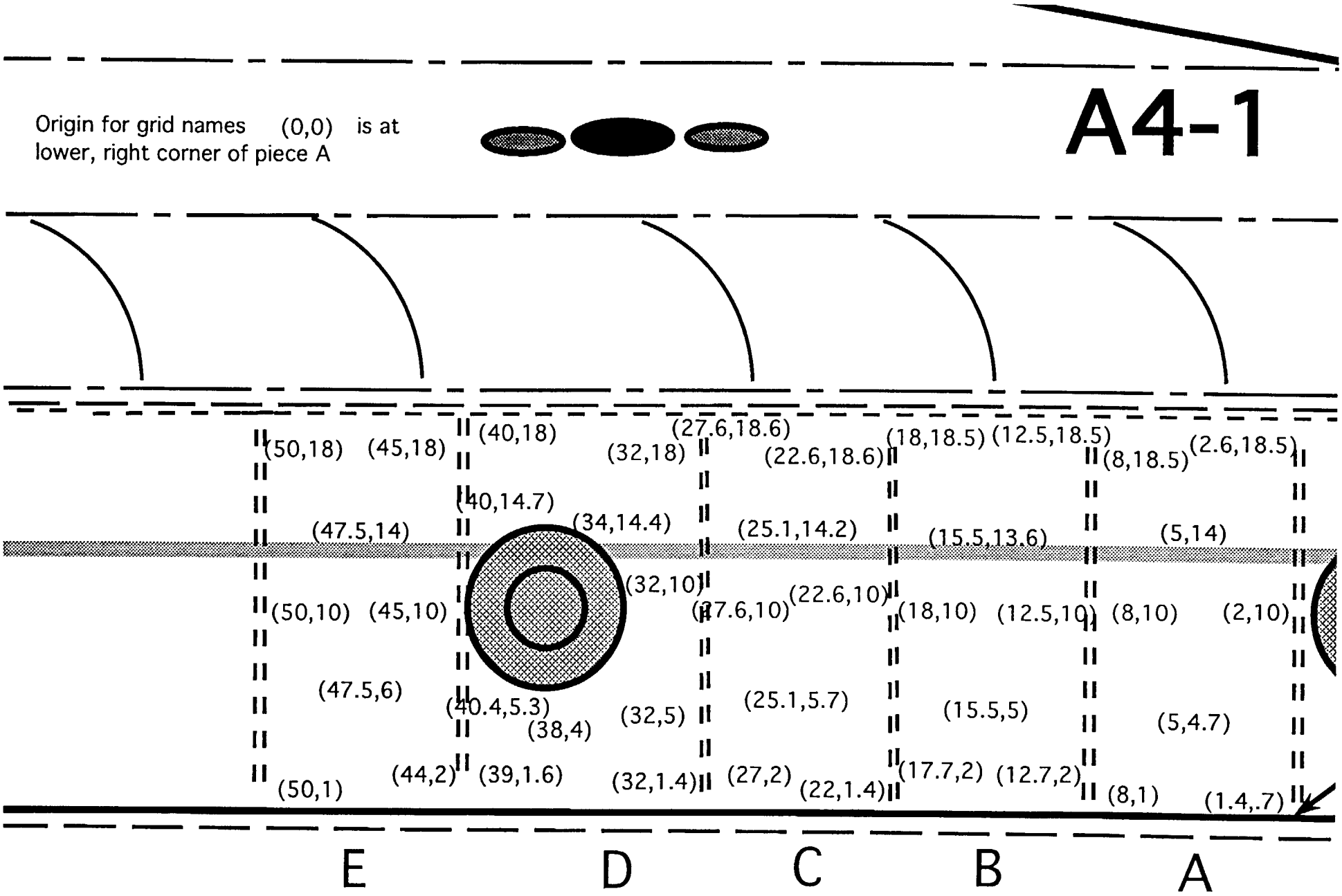
Origin for grid names is at lower, left corner of piece C in the keyhole section .

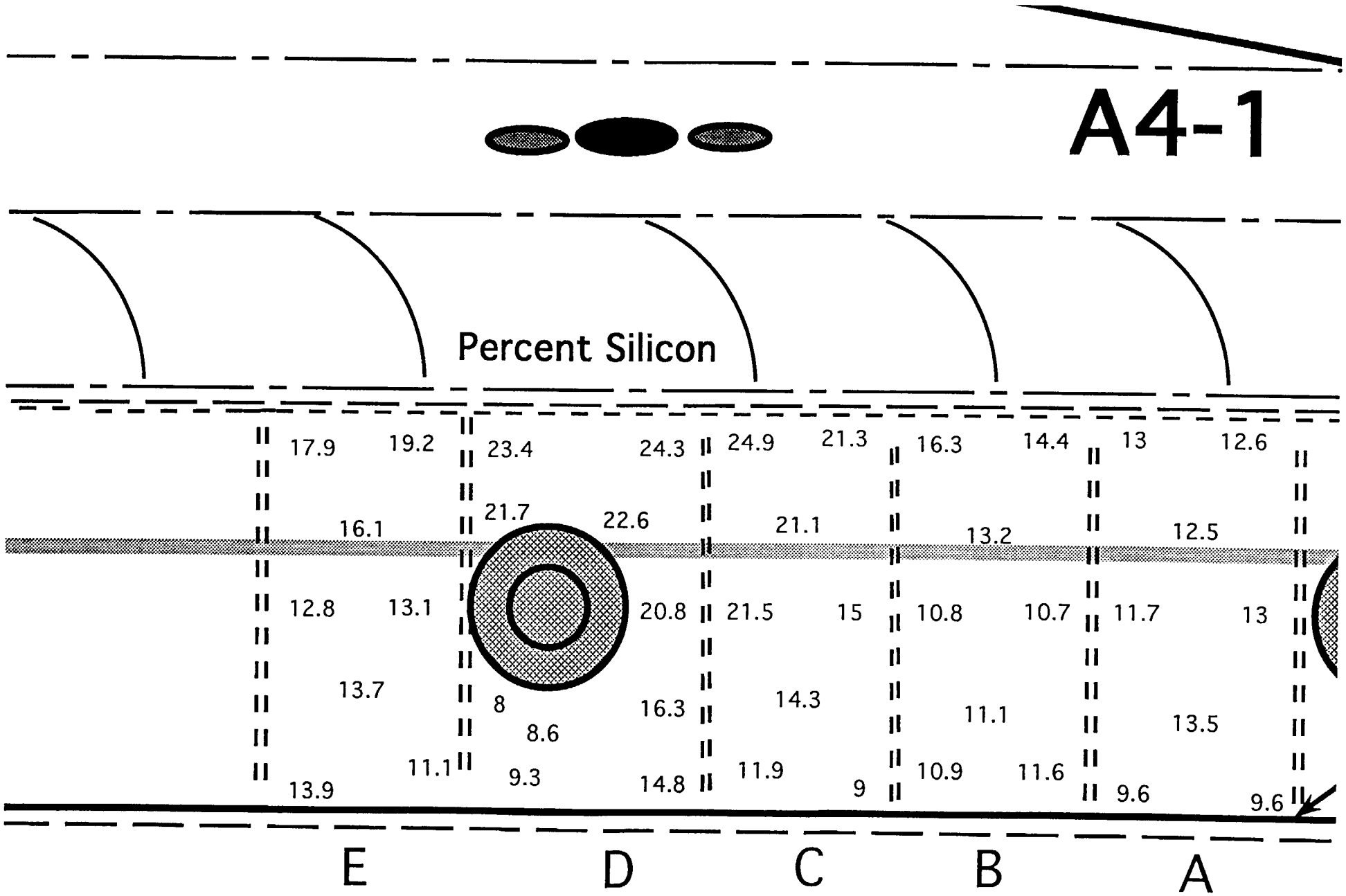
A4-9 (24.5, 5)


Aluminum
Carbon
Oxygen
Silicon
Atomic Percent
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
Angstroms sputtered

Origin for grid names (0,0) is at
lower, right corner of piece A

A4-1




A4-1
Percent Silicon
17.9
19.2
23.4
24.3
24.9
21.3
16.3
14.4
13
12.6
16.1
21.7
22.6
21.1
13.2
12.5
12.8
13.1
20.8
21.5
15
10.8
10.7
11.7
13
13.7
8
16.3
14.3
11.1
13.5
8.6
11.1
9.3
14.8
11.9
9
10.9
11.6
9.6
13.9
9.6
E
D
C
B
A

NAS8-40581 CONTRACT STATUS

SURFACE ELEMENTAL % MAPS ESSENTIALLY COMPLETE

AUGER DEPTH PROFILES CURRENTLY BEING OBTAINED

EXPERIMENTAL RESULTS WILL BE COMPARED WITH RESULTS OF PREDICTIONS OF CONTAMINATION LEVELS FROM ISEM AND MOLFLUX COMPUTER MODELS

TRAILING EDGE LOCATIONS(A4) SHOW THIN BUT WIDESPREAD SURFACE SILICON DISTRIBUTION

DISCOLORED AREAS ON LEADING EDGE (E10) AND "SIDE" (C6) LOCATIONS

TRAY LIPS APPEAR CONTAMINATED BY TRAY COVER GASKETS USED PRE-FLIGHT

TRAY WALLS ESSENTIALLY CONTAMINATED ONLY FROM DC6-1104 ADHESIVE FROM INTERIOR OF TRAYS
RESULTS SUGGEST MINIMAL CONTRIBUTION FROM OTHER POSSIBLE SOURCES

ELEMENTAL SILICON SURFACE %'S APPEAR TO TRACK SOLAR EXPOSURE LEVELS

DISCOLORED AREAS ONLY OCCUR WHERE SURFACE RECEIVED BOTH SOLAR AND ATOMIC OXYGEN EXPOSURE

NAS8-40581 contract status- This chart summarizes the tasks being carried out and the results-to-date. I intend to mention that the experimental results are being compared with predictions from two different contamination deposition models. The computer predictions will be based on the ISEM and MOLFLUX models but the results are not yet reported. The audience at this workshop will be very familiar with the capabilities of these two computer models.

POSA I & POSA II FLIGHT EXPERIMENTS

DEPLOYED ON MIR DOCKING MODULE MARCH 1996

SCHEDULED RETRIEVAL SEPTEMBER 1997

INTERNATIONAL SPACE STATION CONTAMINATION RISK MITIGATION EXPERIMENT

~900 PASSIVE MATERIAL SPECIMENS

POSA I TECHNICAL LEAD JIM ZWIENER, NASA MSFC

POSA II TECHNICAL LEAD GARY PIPPIN, BOEING

PARTICIPATING ORGANIZATIONS NASA MSFC, LaRC, JSC, and LeRC, BOEING, BOEING NORTH AMERICAN, MCDONNELL-DOUGLAS, AZ TECHNOLOGY, IITRI, SHELDAHL, PARKER-HANNIFEN

TWO METEOROID & ORBITAL DEBRIS EXPERIMENTS UNDERGOING SIMULTANEOUS EXPOSURE

This chart summarizes a pair of companion experiments which are currently being flown on the MIR space station. These experiments are the Passive Optical Sample Assembly(POSA) I & II. I will present a little of the background of these experiments, who is involved, and what we plan to do upon retrieval.

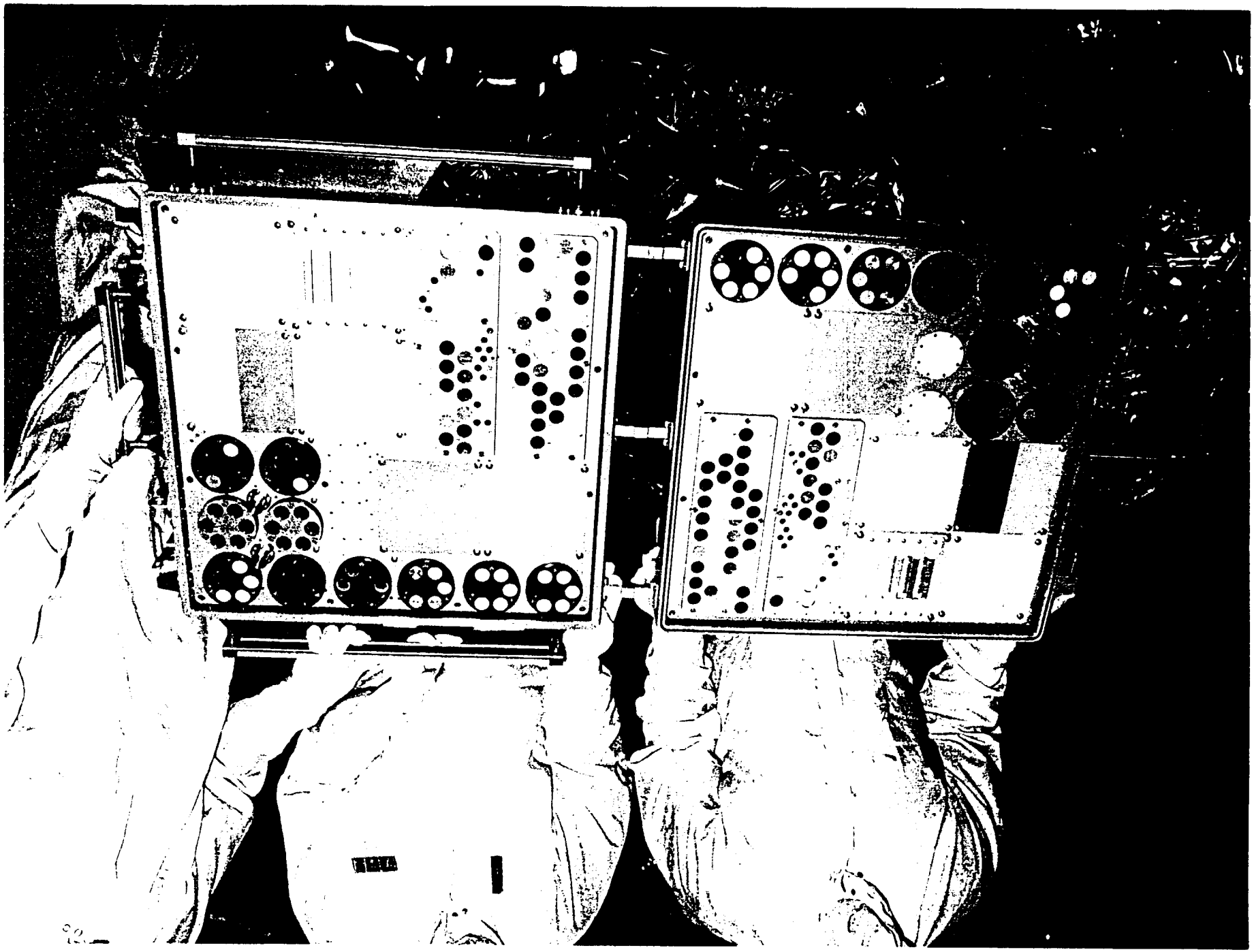
MATERIAL CATEGORIES FLOWN ON POSA II

ANODIZED AND ALODINED ALUMINUMS, WHITE PAINTS, Ag/FEP
KAPTON, OPTICAL WITNESS SAMPLES,
SILICONE RUBBER, FLUOROSILICONE RUBBER, VITON
BLACK PAINTS, CR-39,
"PRE-CONTAMINATED" SURFACES-VARIETY,
MULTI-LAYER INSULATION BLANKET,
CYANATE ESTER RESIN/GRAPHITE COMPOSITE,
BRAYCOTE 601 AND BRAYCOTE 803

POSA I CARRIED NO SILICON-CONTAINING MATERIALS

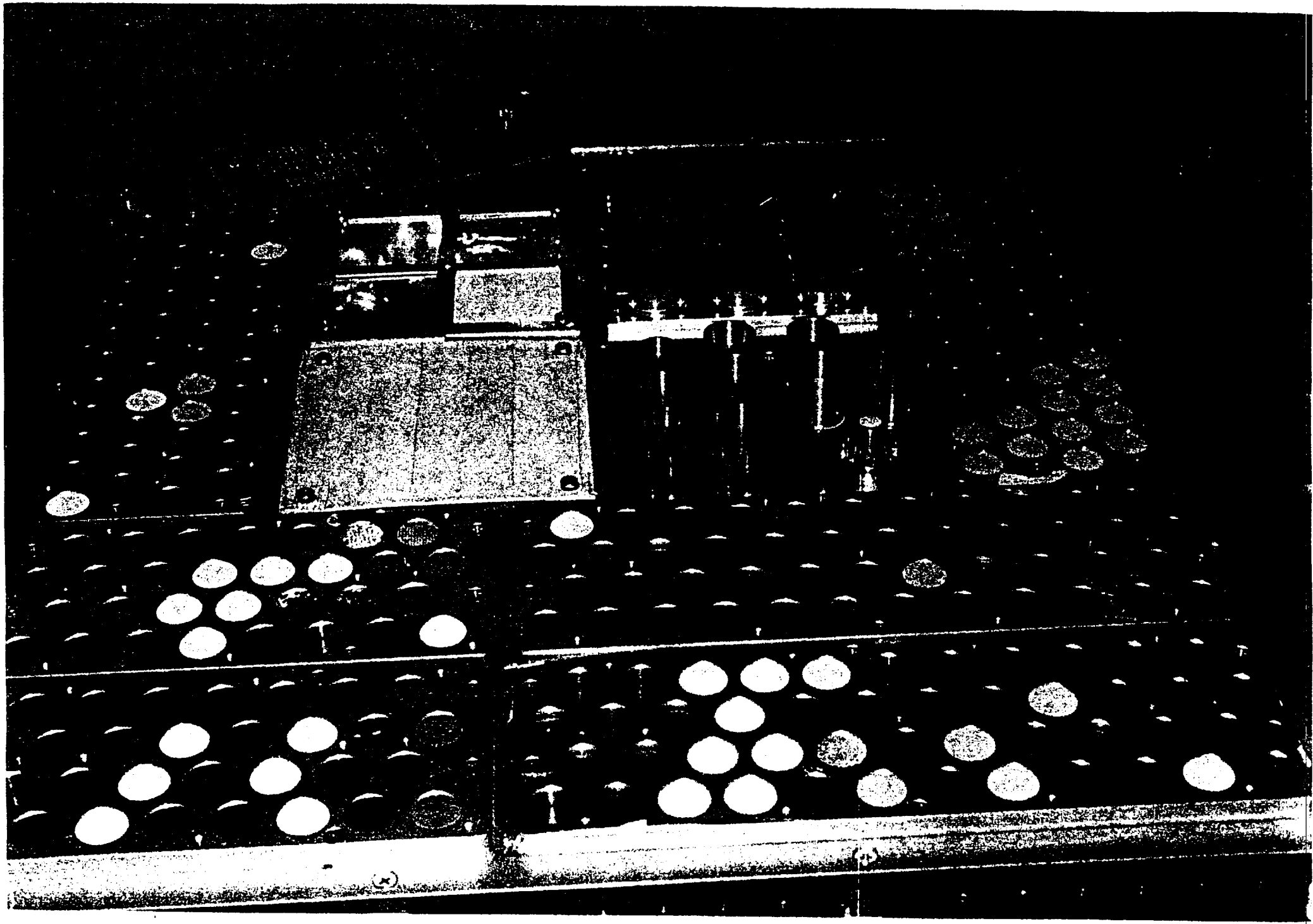
POSA I & II ARE NOT LINE OF SIGHT TO EACH OTHER

This chart describes the types of materials being flown on the POSA II experiment, for which I am the technical leader. I will describe why some of these materials have been chosen and what we expect to learn in general terms.



POSA I, pre-flight This NASA photo shows the POSA I experiment with all specimens mounted, prior to flight. I intend to point out some of the Boeing specimens on this experiment.

POST II, PRE-FLIGHT

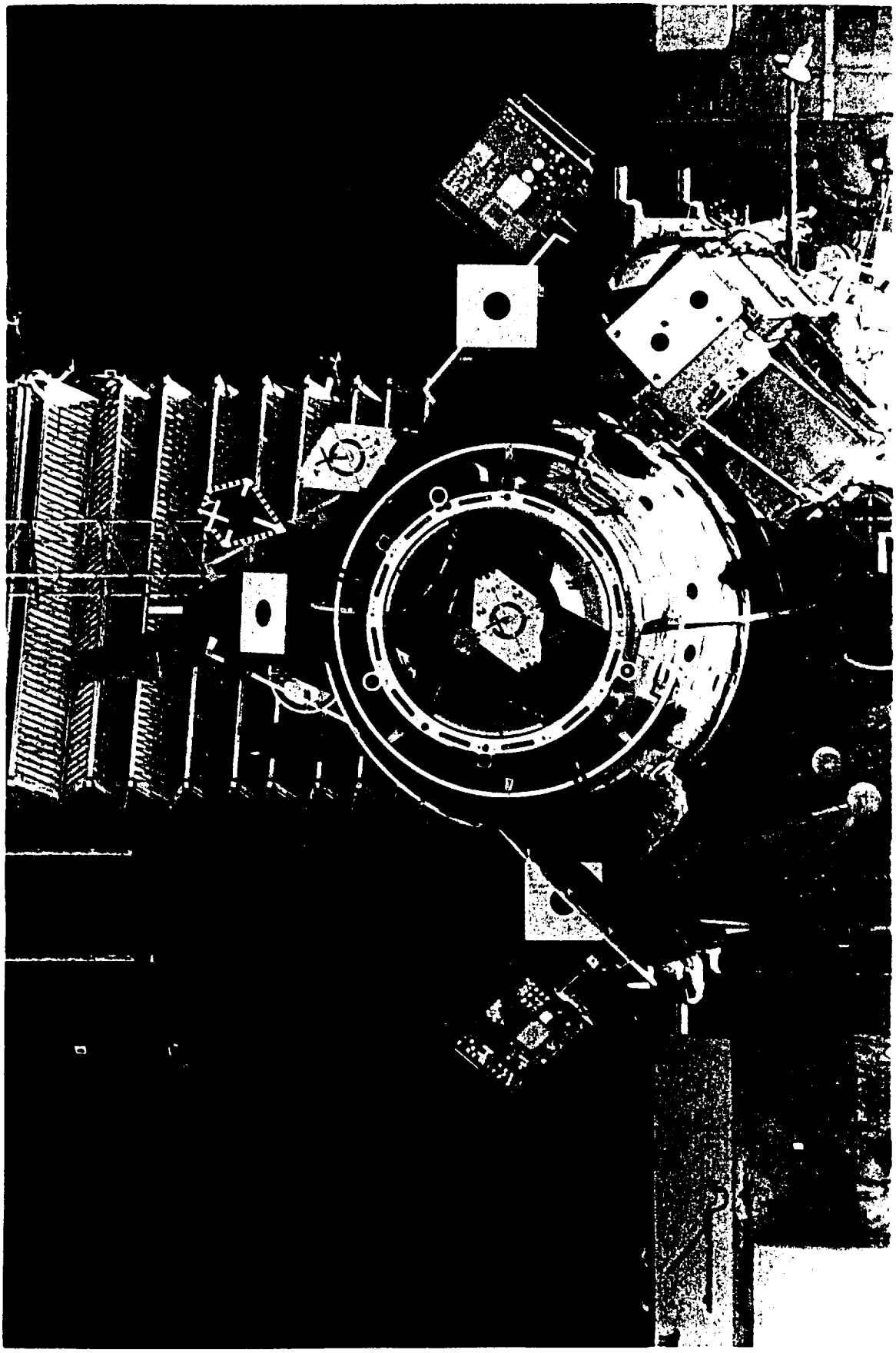


POSA II, pre-flight This photo taken at Boeing shows the assembled POSA II sample holder. I intend to point out some of the different material types being flown, the atomic oxygen concentrators, pre-contaminated specimens, and passive means being used to obtained some time varying exposures for selected material types.

National Aeronautics and Space Administration

STS079-321-035

Lyndon B. Johnson Space Center
Houston, Texas 77058



POSH I & II ON-ORBIT

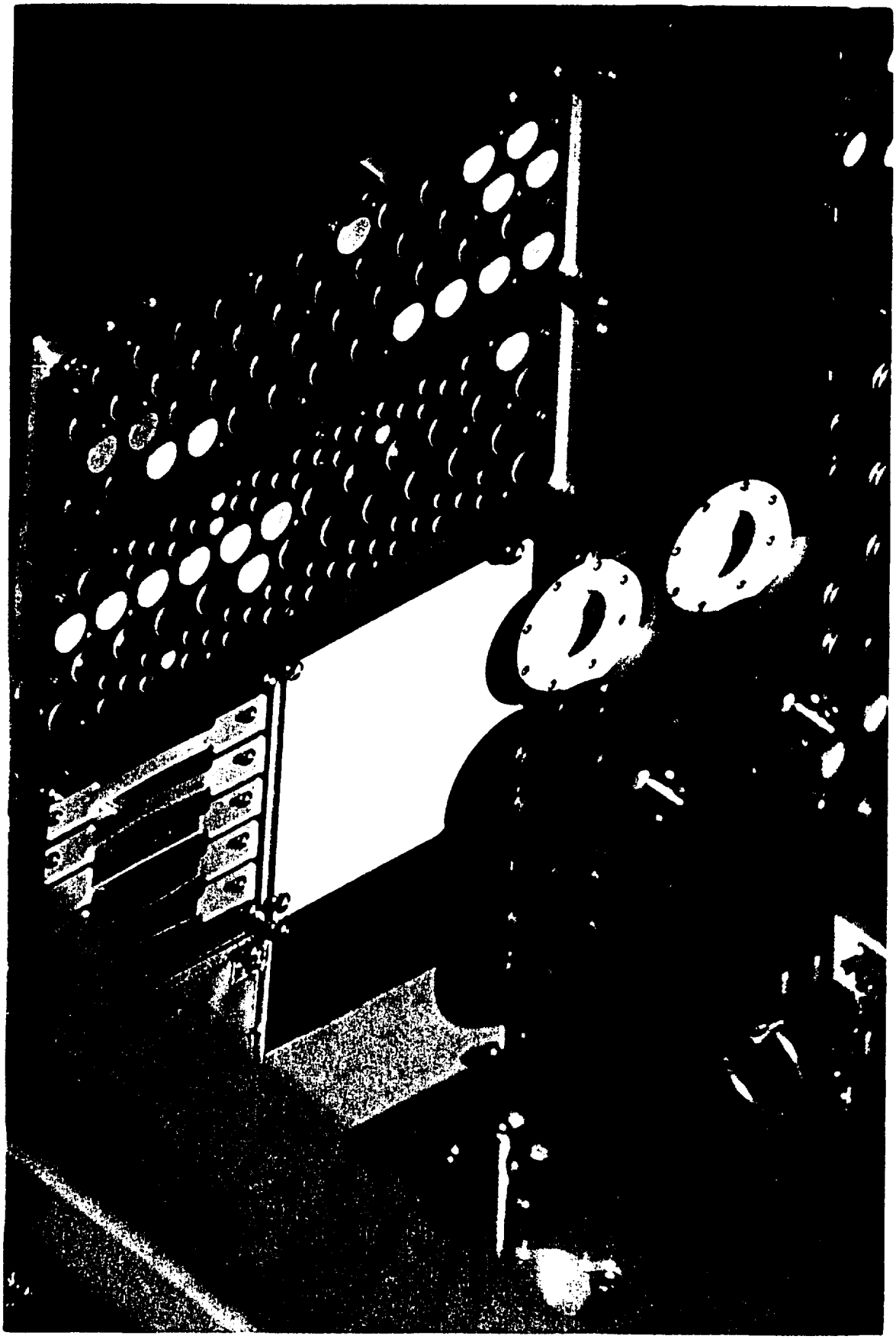
POSA I & II, on-orbit This NASA photo shows the POSA experiments mounted on the docking module attached to the MIR space station. This is the best view available of these two experiments and was taken from a camera in the payload bay of the Space Shuttle.

National Aeronautics and
Space Administration

STS079-325-001

Lyndon B. Johnson Space Center
Houston, Texas 77058

ROSAT, CLOSE-UP ON-ORBIT



POSA I, close-up, on-orbit This NASA photo shows a close-up of the POSA I experiment during the STS-079 rendezvous with MIR. This was about 5 months into the exposure period. The hardware looks to be in excellent condition.

JAPANESE FLIGHT DEMONSTRATION
STS-85
JULY 1997

NASA-LaRC METEOROID & DEBRIS EXPERIMENT
NASA-LaRC, COLLEGE OF WIL.LIAM & MARY, BOEING MATERIALS EXPERIMENT

Project Manager Junilla Applin NASA LaRC

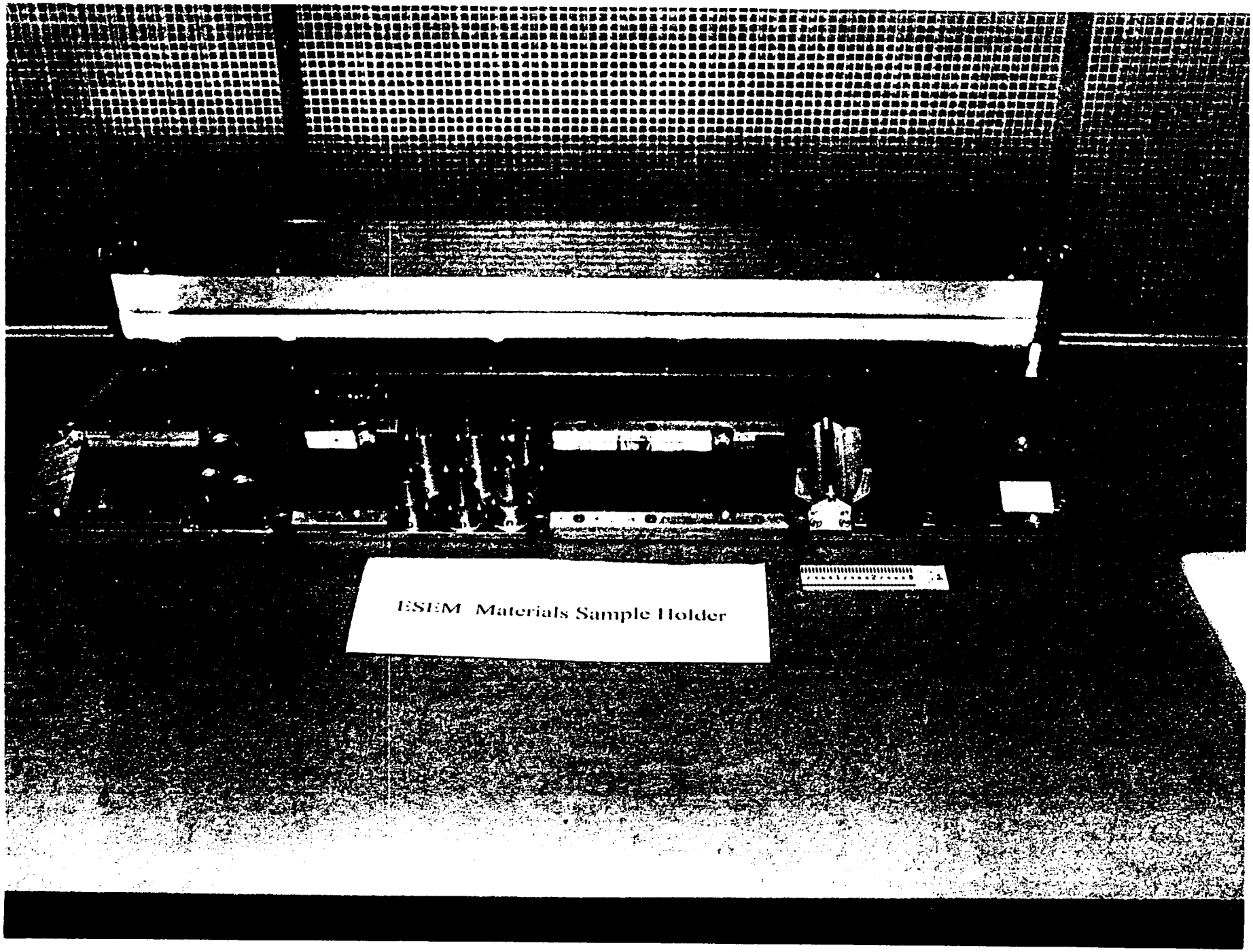
Participants NASA LaRC Bill Kinard, Jim Jones, John Connell, Gale Harvey, Shiela Thibeault
College of William & Mary Robert Orwoll, Richard Kiefer
Boeing Gary Pippin, Gail Bohnhoff-Hlavacek

Japanese Flight Demonstration This chart shows the people involved in a Space Shuttle experiment being flown this July

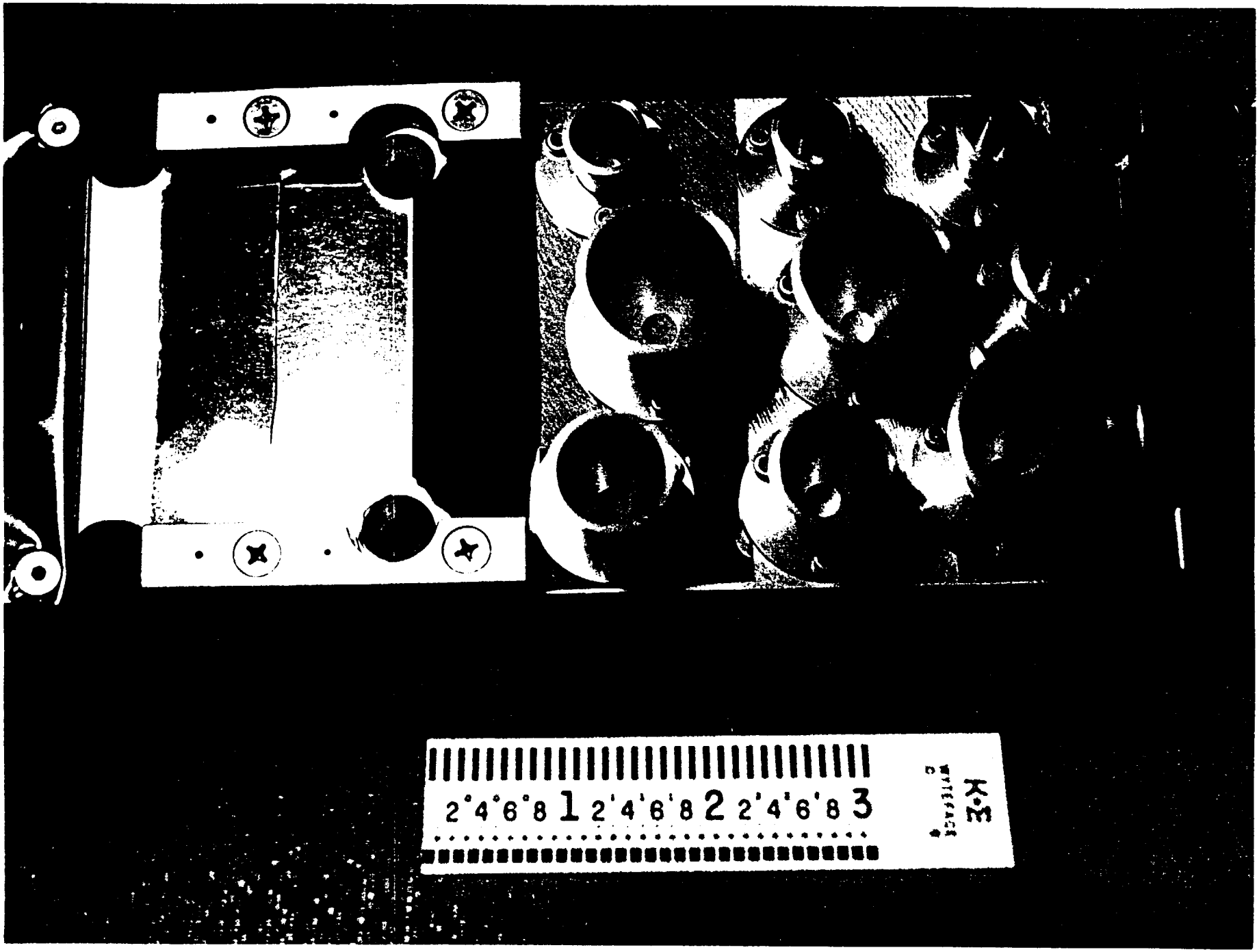
ESEM MATERIAL SPECIMENS

KAPTON KAPTON Laminate Aluminized KAPTON from STS-61
AORAMID TOR COR
Polyetherimide Polyetherimide with BTO coating(2 thicknesses)
Ag/FEP, 10 mil Ag/FEP from LDEF ITO coated FOSR (2 samples, differing ITO thickness)
Cyanate Ester/graphite composite
Viton (V835) Braycoat 601(perfluoroether) on V835 Braycoat 803(perfluoroether) on V835
Silicone (S383) Braycoat 601 on S383 Braycoat 803 on S383
Fluorosilicone
White Paint (BMS 10-79)
Contamination witness plates
Compound parabolic Solar Concentrator - perforated Ag/FEP film
Atomic Oxygen concentrators (x4, x9, x16)

This chart shows the material specimens being flown on the Effects of the Space Environment on Materials experiment. I intend to briefly mention the rationale behind the selection of these specimens, emphasizing that the solar concentrator and atomic oxygen concentrators are attempts to extend the range of measurement conditions generally achieved on Space Shuttle flights.



ESEM, pre-flight This NASA photo shows the material sample holder for the ESEM experiment, complete with the specimens mounted in place. This shows the effective use of the area available for this experiment and I will discuss the details of the layout of the samples.


2 4 6 8 1 2 4 6 8 2 2 4 6 8 3
K-E

This NASA photo shows a close-up of the atomic oxygen concentrators. The acceleration factors expected and issues relating to energy changes in atoms reflecting off the walls of the collectors will be discussed.

REFERENCE STANDARDS USED FOR Si CHARACTERIZATION

ORGANIC SILICONE

HIGH VACUUM SILICONE GREASE RUBBED ONTO GOLD WAFER

INORGANIC SILICATE

1000A THICK SiO2 LAYER ON A SILICON WAFER

Si Sp PEAKS USED FOR CHARACTERIZATION

SILICATEPEAK AT ~103.5 ev, PEAK WIDTH ~1 ev

SILICONES PEAK AT ~102.5 ev, PEAK WIDTH ~1.5 ev

CARBON 1s REFERENCE PEAKS ALSO OBTAINED FOR EACH BOLT HEAD MEASUREMENT

SINGLE BROAD PEAK IN THE ~99-105 ev RANGE IS CURVE FIT TO TWO PEAKS

This chart is a background chart which will be used to describe the measurements on the LDEF tray clamp bolt heads. It is to show the detailed level of analysis carried out to arrive at the results shown on subsequent charts.

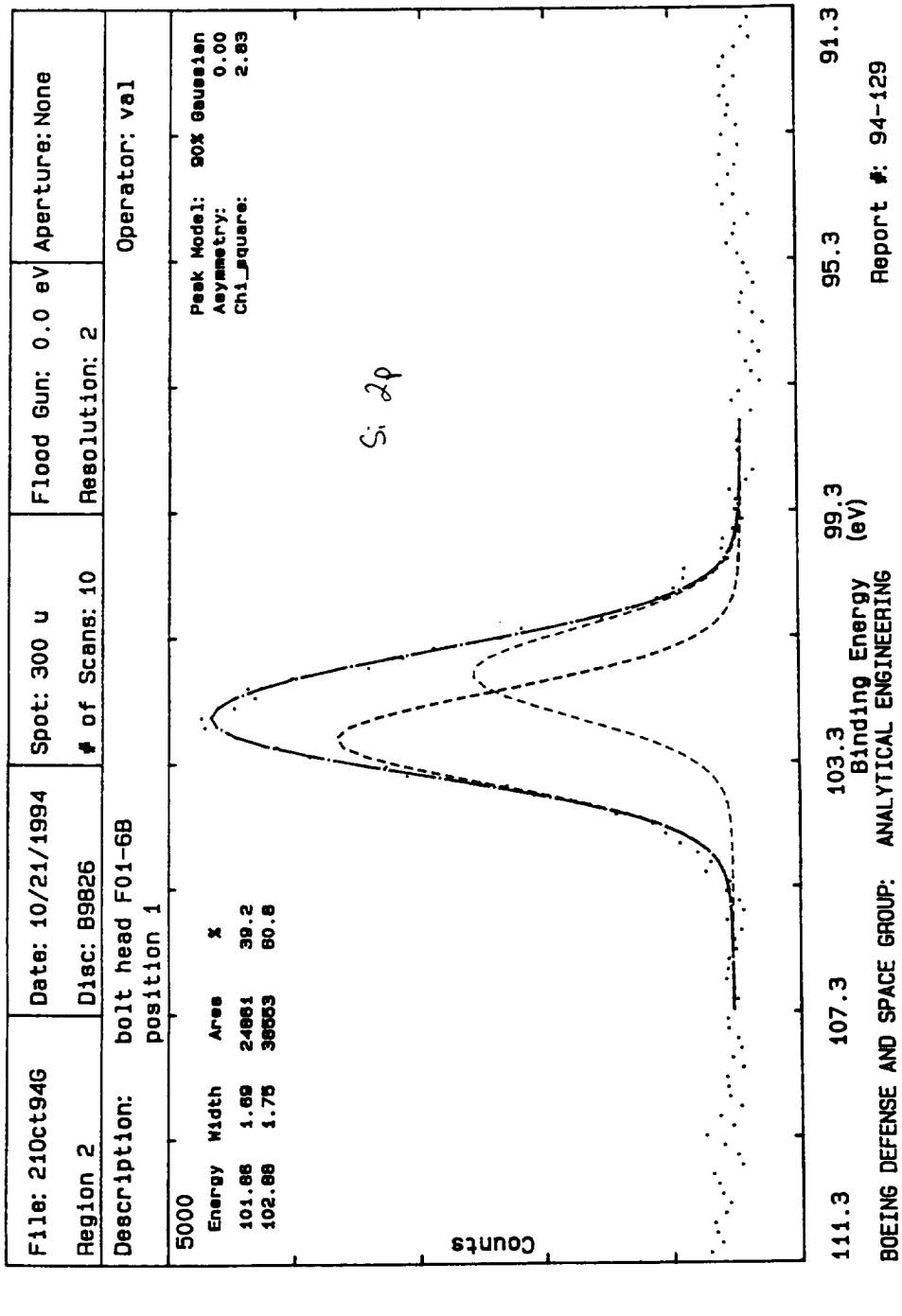


Figure G-27. Silicon 2p spectrum for bolt F1-6b, position 1.

This chart is a detailed energy spectrum obtained using surface X-ray photoelectron spectroscopy(XPS). This spectrum is for silicon and shows the separation of the measured peak into its two components representing inorganic and organic based silicon deposits.

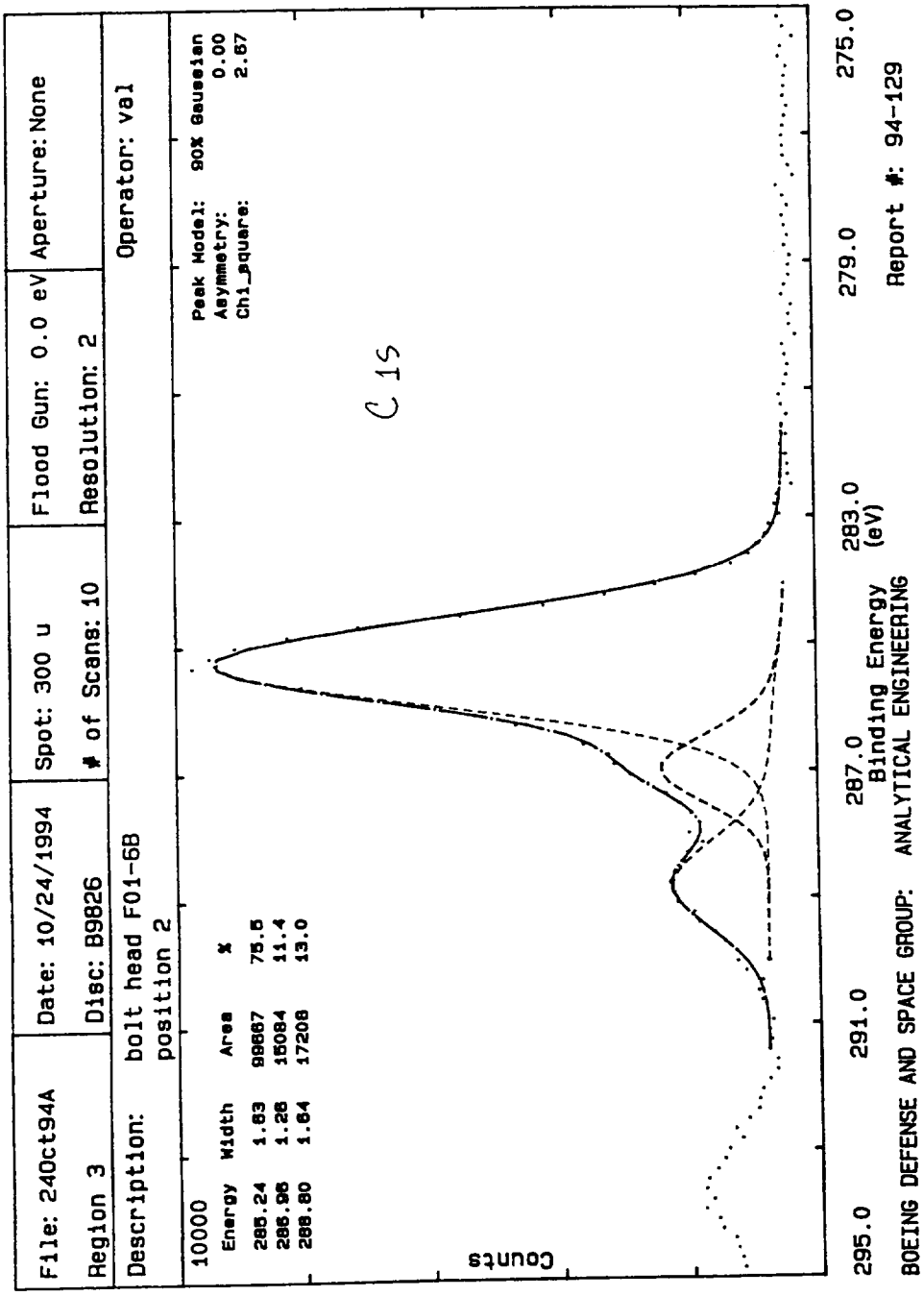


Figure G-28. Carbon 1s spectrum for bolt F1-6b, position 2.

This chart shows a reference carbon 1s spectrum used as a standard to precisely establish the energies of the peaks shown in the previous silicon XPS measurement.

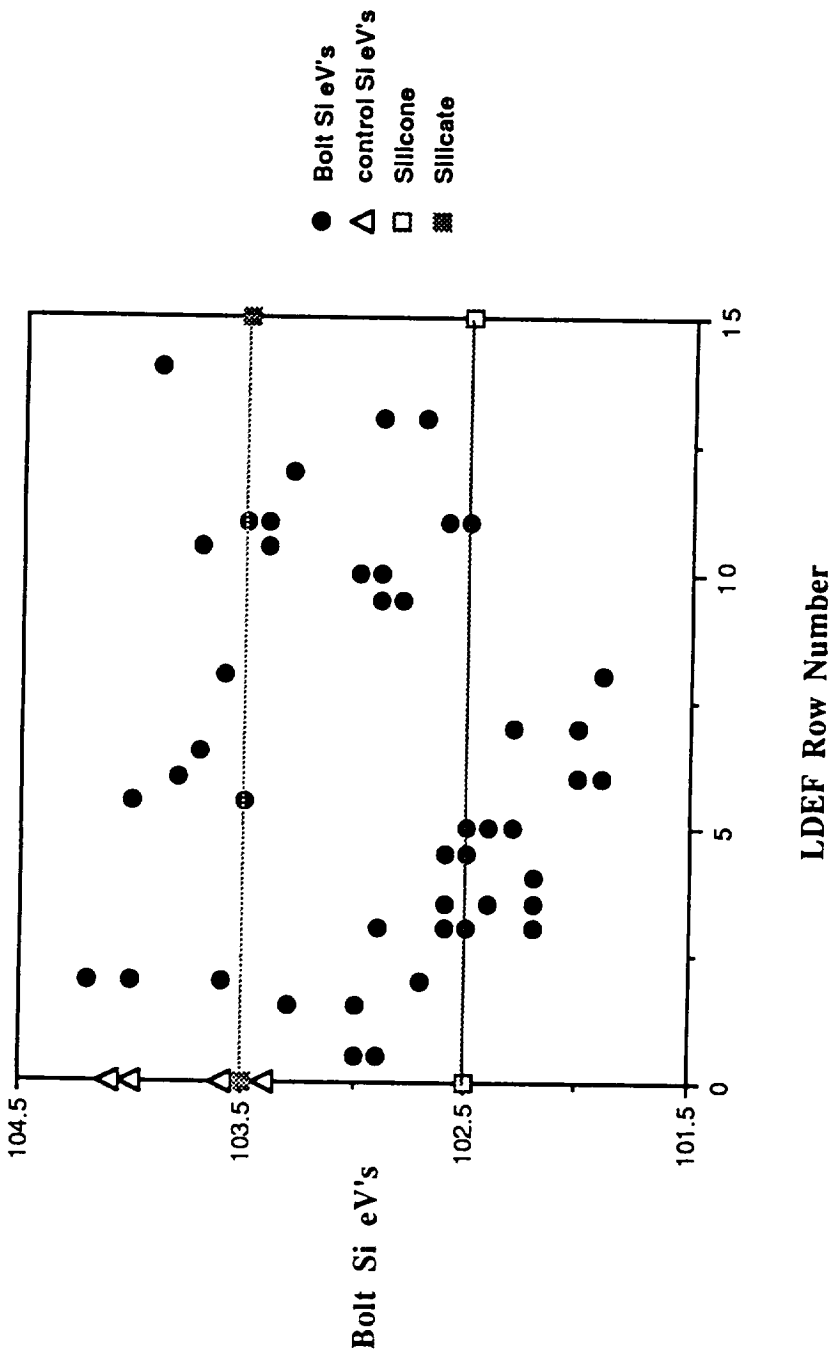
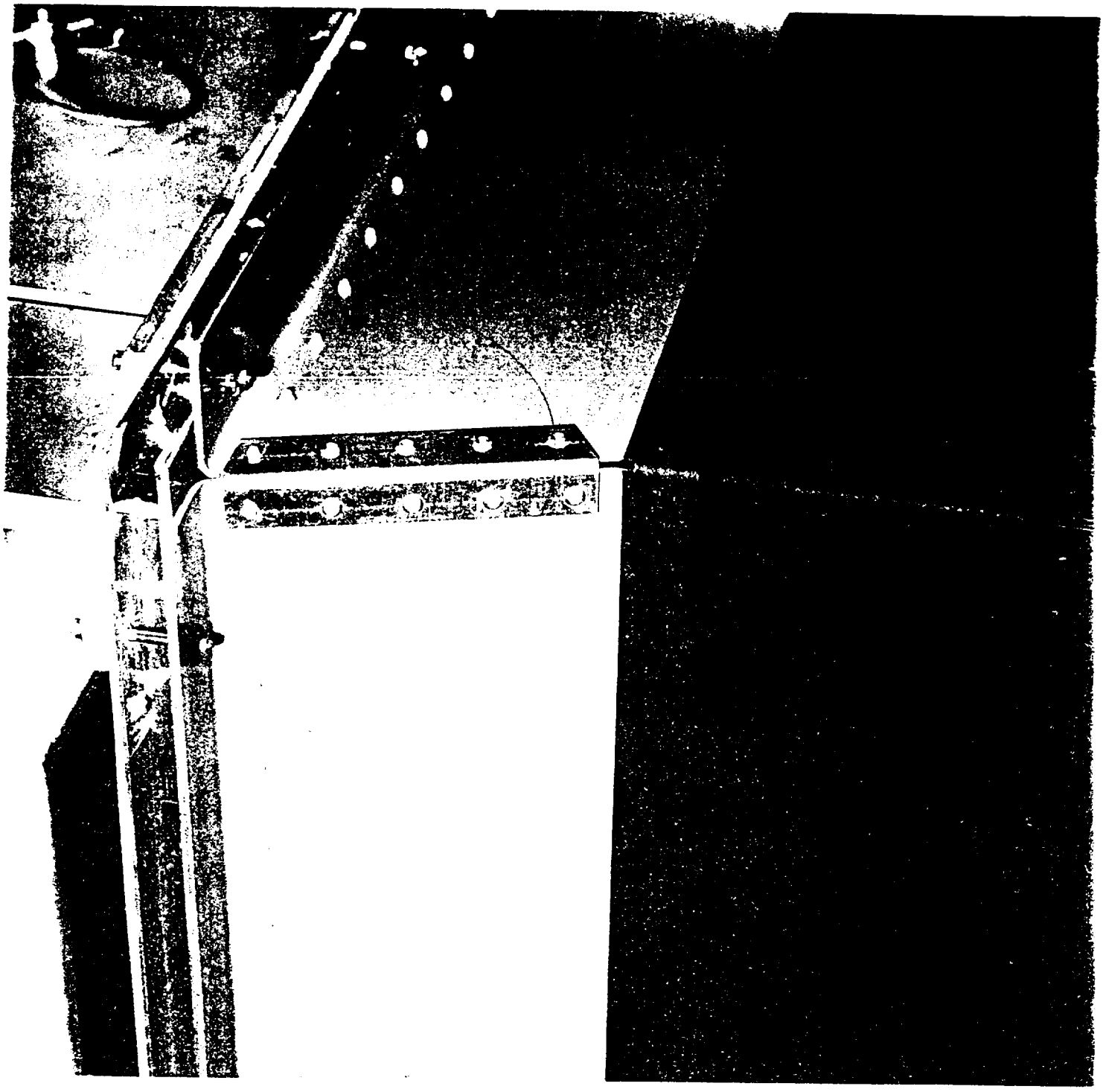


Figure 17. Results of high resolution ESCA measurements on selected stainless steel bolt heads from LDEF.

This chart summarizes the results of the XPS measurements made on selected tray clamp bolt heads from the Long Duration Exposure facility. The results indicate the presence of silicone based material for areas which had considerable atomic 0xygen exposure on-orbit, indicating a source of silicone contamination after the LDEF was captured by the Space Shuttle.



JOINT ANNUNCIATION PLUG
GASKET MATERIAL

Contamination from Gasket Material This NASA photo shows contamination deposits which can be attributed to pre-flight outgassing by silicone gasket material used as part of the tray covers for the LDEF experiment trays both pre- and post-flight. The discoloration is due to the actual on-orbit exposure conditions.

CONTAMINATION CONTROL FOR COMMERCIAL VEHICLES

QUESTION IS ALWAYS "HOW MUCH IS ENOUGH?"

IDENTIFY THE MOST CONTAMINATION-SENSITIVE STEPS

SEEK TO MINIMIZE COST OF NECESSARY OPERATIONS

FREQUENT CLEANLINESS VERIFICATION TESTING TO DEFINE PROCESS

LESSONS FROM EARLIEST HARDWARE APPLIED TO LATER UNITS

This summary slide is to relate findings from the experiments described in this talk to issues of importance to people building commercial satellites.